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# USER GUIDE FOR CONVERSION TO DUAL FUEL OPERATION OF EMD 645 ENGINES ON NAVY MUSE GENERATOR SETS

by

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13. ABSTRACT (Maximum 200 words)  Conversion of the Navy's Mobile Utilities System Equipment (MUSE) diesel generators to dual fuel (natural gas plus diesel fuel) operation to reduce their NOx (nitrogen oxide) emissions is described. The Navy maintains a fleet of 60 such units, powered by EMD 645 engines, that range in size from 1,500 kW to 2,500 kW. A means for providing low-NOx MUSE generators that will not compromise the operational capability of the fleet is required.  This guide is based upon the experience gained from converting a 1,500 kW MUSE unit to dual fuel operation (the unit is currently installed and operating at King's Bay Naval Station in Georgia). Information on the conversion process, operation, maintenance, and the cost of the dual fuel conversion are provided.					
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## EXECUTIVE SUMMARY

Steps are described for converting the Navy's Mobile Utilities System Equipment (MUSE) diesel generators to dual fuel (natural gas plus diesel fuel) operation to reduce their NOx (nitrogen oxide) emissions. The Navy maintains a fleet of 60 such units, powered by EMD 645 engines, that range in size from 1500 kW to 2,500 kW. As the current MUSE diesel units meet few existing local NOx emission regulations, newer more-restrictive regulations (a trend now ensured with the proposed further tightening of the National Ambient Air Quality Standards) will ensure that the areas accessible to MUSE diesel generators will continue to decrease. Therefore a means for providing low-NOx MUSE generators that will not compromise the operational capability of the fleet is required.

This guide is based upon the experience gained from converting to dual fuel operation a 1500 kW MUSE unit that is now installed and operating at the King's Bay Naval Station in Georgia. Information on the conversion process, operation, maintenance and the cost of the dual fuel conversion are provided.

NOx emission reductions of 70 percent were demonstrated with this unit; NOx reductions of greater than 90. per cent are achievable using an additional secondary ignition cell. Capital requirements for the retro-fit dual fuel conversion of a 2500 kW MUSE engine generator are shown to be \$158. per kilowatt (including the secondary ignition cells). This is compared to the cost of replacing this same MUSE unit with a new spark-ignited, low-NOx, natural gas engine. The cost for the latter is \$560. per kilowatt. For a 2500 kW MUSE unit, these numbers translate into a capital savings of over \$1.0 million if the option of retro-fitting for dual fuel operation is chosen. Operating costs for dual fuel (natural gas) operation of MUSE generating sets are also substantially reduced over that of unmodified diesel operation. For the case evaluated, the cost for natural gas firing is 4.1 cents per kW-hr while that for diesel firing is 8.9 cents kW-hr.

A further major operational (strategic) advantage of the retro-fit dual fuel unit over that of a new, spark-ignited, natural gas engine is that it can be made to operate as either a full diesel or a full natural gas unit.

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This project would not have been possible without able assistance of many people. A technically challenging aspect of the project was automation of the controls which was required to ensure the safe handling of natural gas within the engine house. Master Chief Petty Officer (retired) Ronald Kluender's intimate knowledge of the original MUSE control system and Scott Jensen's thorough understanding of the ECI dual fuel conversion engine control unit (ECU) made possible the successful integration of those two control systems. John Pesar, Program Manager for MUSE, made available a 1,500 kW MUSE engine generator set to serve as the prototype and approved use of MUSE personnel to assist with the conversion to dual fuel operation. MCPO Russell Dominy, MCPO Jim Riley, PO1 Anthony Fourage, and PO1 Rodney Hood also assisted.

Delma Keene of SUBASE King's Bay provided a field test site along with funds from NAVSEA to install the dual fuel unit at King's Bay. He and Bill Strickland arranged for installation of the unit there, oversaw its operational schedule, and provided a strong presence in resolving field operational problems. Their assistance was invaluable. Ralph Kerwin of Gage Babcock (fire safety consultants) helped to define hardware and procedures for safely operating the MUSE engine generator while using natural gas. Kevin Beaty of Southwest Research Institute (SwRI) recognized the potential value of the results of this project to the efforts to GasRail, Inc. for developing lo-NO<sub>x</sub> engines for locomotive use, and provided flowrate measuring and data logging instrumentation for the project. Jack Smith and Butch Quip of SwRI installed that instrumentation.

George Warren and Ed O'Neil of NFESC provided structural recommendations for the installation and mounting of a new compressor and water pump. Wayne Tanaka of the Natural Gas Vehicle Division of the Southern California Gas Company (SCGC) made special arrangements for weekend use of the SCGC compressed natural gas tanker along with a high-capacity pressure reduction manifold and the personnel to operate them for shakedown tests. Manny Perez, Bob Saunders, Ken Hanzlick, and Galen Marks of NFESC gave up their weekends to assist with measurements during the shakedown tests.

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## 1.0 INTRODUCTION

This user data package describes steps in the conversion of the Navy's Mobile Utilities System Equipment (MUSE) transportable diesel generator sets from diesel to dual fuel (natural gas plus diesel fuel) operation. These diesel generator sets are part of a fleet of 60 such units maintained by the Navy's MUSE detachment for deployment to Navy, other military, and sometimes civilian uses throughout the world (Ref 1-1). The units range in size from 750 to 2,500 kW and are powered, largely, by EMD 645 engines manufactured by the ElectroMotive Division of the General Motors Corporation. The engines are medium-speed (750 or 900 RPM), have 8 to 20 cylinders with cylinder displacements of 645 cubic inches, and use a 2-stroke operational cycle. This guide is based on the experience gained from converting to dual fuel operation a 1,500-kW MUSE unit that is now installed and operating at the King's Bay Naval Station in Georgia (Fig. 1-1). The technology used for this conversion was provided by ECI Inc., Tacoma, Washington. MUSE personnel, assisted by ECI technicians, installed the required engine modification hardware and the electrical and engine skid modifications.

### 1.1 Environmental Compliance and Navy Need

Of the Navy's many diesel engines, those installed in its MUSE generating equipment for temporary (<4 years) stationary electrical power were the first off-road Navy engines to be affected by environmentally-mandated nitrogen oxide ( $\text{NO}_x$ ) emission regulations. As MUSE units are transportable but are typically employed at a given site for periods exceeding that normally used to define 'temporary power' (temporary power is often defined as service not exceeding one year), they must comply with air pollution regulations that apply to stationary power generating equipment. But regulatory emission standards for stationary power units are highly variable as they both depend upon the degree of nonattainment in the surrounding air control region and upon the air control district in which the region is located. Therefore MUSE units must have a capability for meeting these variable standards as the units are moved from one location to another. Such regulations can vary from none to those applicable in the South Coast Air Quality Management District (SCAQMD) of California, where emission limits are <1.0 gram/horsepower-hour (gm/HpH). As  $\text{NO}_x$  emissions from current MUSE units range anywhere from 12 to 16 gm/HpH, attempts to operate them in areas in which they do not comply with emission regulations could result in the imposition of heavy fines and as well as ordered shut-down by civilian authorities. Therefore a means for reducing  $\text{NO}_x$  emissions from them is required.

The following factors and criteria were determined to be important in evaluating approaches for reducing  $\text{NO}_x$  emissions from MUSE diesel generator sets: (a) most MUSE engine generator units are driven by an EMD 645 engine, (b) when burning diesel fuel, these EMD engines do not meet the emission requirements in many areas of the country where the Navy operates, (c) although transportable, MUSE units must comply with emission regulations that apply to stationary devices because of their extended time on site, (d) the required transportability of the MUSE units limits the types of  $\text{NO}_x$  emission control technology that can

be used with them, (e) the large number of MUSE units in inventory and the cost of their replacement requires that a retrofit rather than a replacement technology be acquired for reducing NO<sub>x</sub> emissions, (f) a capability for firing diesel fuel must be maintained to meet the Navy's operational commitments, (g) full generator power capability must be maintained, (h) reliability equal to or better than that for the diesel-only configuration is needed, (i) the technology selected must be within the technical expertise of MUSE and onsite personnel who will be required to operate and maintain the modified units, and (j) operational costs must not escalate appreciably beyond those incurred when the MUSE unit is operating as a diesel-only engine.

## **1.2 Selection of NO<sub>x</sub> Control Technology**

Two general approaches can be used for reducing NO<sub>x</sub> emissions from diesel engines: (a) modification of the engine combustion process so that fewer NO<sub>x</sub> species (nitric oxide, NO, and nitrogen dioxide, NO<sub>2</sub>) are generated, and/or (b) treatment of the exhaust gases to destroy the NO<sub>x</sub> species generated to prevent their emission into the atmosphere. Of the many variations of these approaches that have been investigated, two were considered for application to MUSE diesel generator sets: (a) conversion of the engine to dual fuel operation, and (b) the use of selective catalytic reduction (SCR) for treatment of the engine exhaust stream. Although SCR offers the advantage of bringing the MUSE engine generators into immediate full compliance with the most restrictive of NO<sub>x</sub> emission regulations, its application would add significant cost, complexity, and size (requiring that an additional module be transported) to the transportable MUSE engine generator set, and would also introduce ammonia (NH<sub>3</sub>, a hazardous chemical) at the operating site. NH<sub>3</sub>, which is used as the chemical reductant for NO<sub>x</sub>, is not only a hazardous chemical, but, itself, presents a threat to the environment. Therefore the SCR process using NH<sub>3</sub> as the reductant was not considered to be a practical solution for reducing NO<sub>x</sub> emissions from MUSE diesel generator sets.

The recommended application of dual-fuel technology (or alternative fuel) is based upon a retrofit conversion kit designed, specifically, for the EMD 645 engine by Energy Conversions, Incorporated, Tacoma, WA. The performance, reliability, and emissions reduction of that conversion technology have been demonstrated in a single application on two tandem locomotives used for coal line-haul operations on the Burlington and Northern Railway between Montana and Wisconsin (Ref 1-2). Liquefied natural gas (LNG) from a separate LNG fuel car was used to fuel the tandem locomotives, and NO<sub>x</sub> reductions of nearly 70 percent (to 4.0 from the 12.0 gms./Hph produced when burning diesel fuel) were achieved. Because of these demonstrated results, because no other competing technology could make similar claims with the EMD 645 engine, and because this technology satisfied the criteria for selection of a MUSE NO<sub>x</sub> reduction technology (discussed above), it was selected for installation and testing on a 1,500 kW MUSE diesel generator set.

## **1.3 Installation and Testing of Prototype Dual Fuel MUSE Diesel Generator**

The retrofit, dual fuel conversion was completed in July 1995 at the Construction Battalion Center in Port Hueneme, California. Although previously tested in a locomotive application, it had not been used for stationary power. And although the application to stationary power is, in ways, not as complex as that for locomotives, it is different and presents other

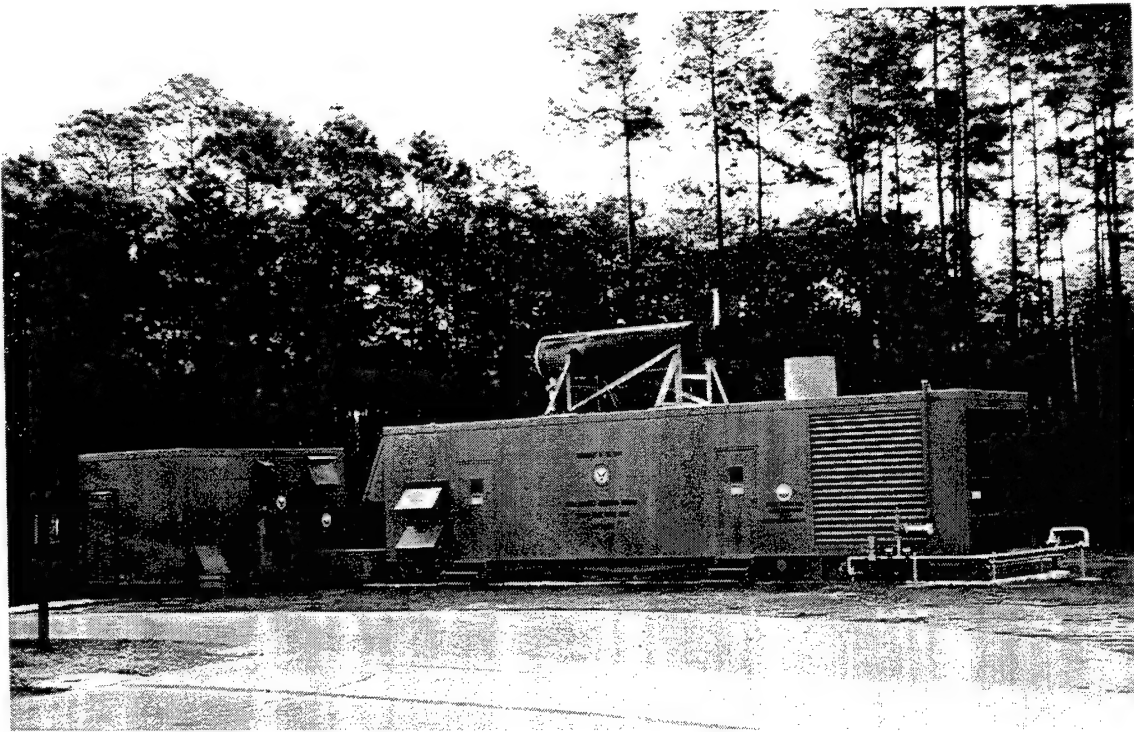


significant challenges. To meet these new challenges, to accommodate the use of natural gas within the MUSE unit, and to provide a capability for the remote operation of the engine generator unit, a new automated control system was designed and installed along with the dual-fuel conversion. Operational checkout tests of the modified unit provided the emissions data that are summarized in Table 1-1. The tests also showed: (a) that the unit could be started, electrically synchronized with a grid, stopped, and otherwise controlled remotely, (b) that full engine generator set power could be produced, and (c) that NO<sub>x</sub> emissions could be reduced by 65 percent, the approximate level anticipated by the dual fuel conversion. The modified unit was then transported to SUBASE King's Bay Georgia where it is now undergoing field testing. Further engine efficiency, fuel usage, power, and emissions data will be obtained during the field test period along with maintenance and other operational and control data.

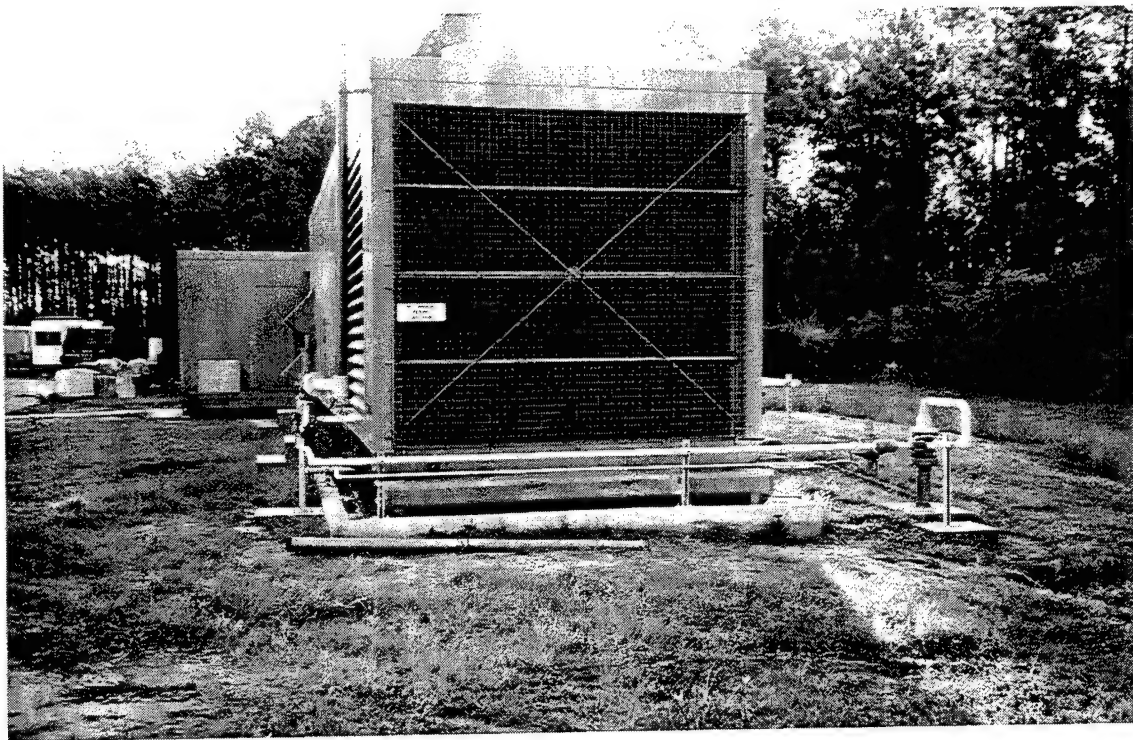
#### **1.4 Organization of the Guide**

This guide contains the information necessary for installing, operating, and maintaining the dual fuel conversion hardware supplied by ECI Inc., Tacoma WA, when used on MUSE diesel generator units that utilize the EMD 645 engine. Section 2 reviews some of the factors involved in NO<sub>x</sub> production in 2-stroke diesel engines and some of the efforts that have been undertaken previously to minimize those emissions. Suggestions are included for making further important reductions in NO<sub>x</sub> emissions from the EMD 645 engines. Section 3 describes the fundamental elements of the ECI dual fuel conversion kit, and Section 4 provides detailed descriptions and installation instructions for the conversion sub-systems, as defined for this new application. Section 5 describes operational procedures of the converted unit and Section 6 discusses field site installation, maintenance, and training requirements. Section 7 provides capital and operating costs for the retrofit, dual-fuel MUSE diesel generator.





(a) Side view of switchgear, interconnecting cable housing, and engine house.



(b) End view showing natural gas supply line.

Figure 1-1. MUSE 1,500 kW dual-fuel engine generating set at SUBASE, King's Bay, Georgia.

Table 1-1. Comparison of Measured Emissions Before and After Dual-Fuel Conversion

Engine			Emissions		
	Fuel	Power (hp)	NO <sub>x</sub> (grams/hph)	CO (grams/hph)	Particulates (grams/hph)
Before Conversion	Diesel	2,119	10.5	0.25	0.35
After Conversion	Dual Fuel	2,119	2.40	9.2	0.211
	Dual Fuel	2,402	3.42	11.4	---

## 2.0 NO<sub>x</sub> REDUCTION FOR LARGE, TWO-STROKE DIESEL ENGINES

Of the many combustion devices having large commercial usage, diesel engines have provided the greatest technical challenges to achieving significant NO<sub>x</sub> reductions. Two general approaches can be used to reduce NO<sub>x</sub> emissions from them: (a) modification of the engine combustion process so that fewer NO<sub>x</sub> species (nitric oxide, NO, and nitrogen dioxide, NO<sub>2</sub>) are generated, and/or (b) treatment of the exhaust gases to destroy the NO<sub>x</sub> species generated and to prevent their emission into the atmosphere. As diesel engines are lean-burn (stoichiometrically, fuel lean), the catalytic reactors used by spark-ignited gasoline engines to reduce NO<sub>x</sub> and hydrocarbon emissions and which require near-stoichiometric combustion, are not effective for reducing the concentrations of the same pollutant species from diesel exhausts. Further, diesel engines operate at higher compression ratios than gasoline engines and combustion in them proceeds according to a complex, heterogeneous diffusion process as opposed to the simpler, easier-to-control, homogeneous flame propagation that characterizes gasoline engine combustion (see Fig. 2-1). The higher compression ratio of the diesel engine leads to its greater efficiency and the diffusion-controlled combustion is what permits its operation at higher pressures without the occurrence of destructive knocking. However, both of these factors lead to higher combustion temperatures and increased NO<sub>x</sub> production in the diesel engine.

Most of the work for reducing NO<sub>x</sub> emissions from diesel engines has been with smaller sized engines. Little research has been carried out on engines as large as the EMD 645. And as the complexity of combustion increases and one's ability to control those processes decreases with engine size, progress in NO<sub>x</sub> emissions reduction from larger engines has been comparably slow. However, as characterization of the fundamental processes in diesel engines improves, the results for controlling NO<sub>x</sub> emissions from both large and small engines may improve. The Navy's Office of Naval Research (ONR) is sponsoring fundamental research (see Refs 2-1, 2-2, and 2-3) on the control of NO<sub>x</sub> emissions from the larger engines used for boat and ship operations. Those results could also find an application with MUSE engines. However, the practical application of that research, if successful, is several years in the future. A further complication with the EMD 645 engines is that they are 2-stroke engines. This reduces the number of engine parameters available for controlling or altering the internal engine processes for the purpose of NO<sub>x</sub> reduction. Further, most work on NO<sub>x</sub> reduction from diesel engines has been on those of the 4-stroke design. Therefore, the quantity of engine research to draw on for reducing NO<sub>x</sub> emissions from the EMD 645 engine is limited.

### 2.1 Exhaust Gas Treatment

Exhaust gas treatment provides one option for significantly reducing NO<sub>x</sub> emissions from diesel engines, although the additional equipment and chemicals required for its implementation works against its application on MUSE units. Two such approaches are available commercially; others are being developed. Those available commercially use a chemical reductant either with catalysts (selective catalytic reduction (SCR)), or without catalysts (selective non-catalytic reduction (SNCR)). The reductants used are usually ammonia or a related compound such as

urea. Other than the identification of a useful chemical additive, the development of an appropriate catalyst is the major technical problem in the development of a useful SCR approach. Although SNCR requires no catalyst, other chemical routes and temperatures for the destruction of  $\text{NO}_x$  must be used. The general features and flow paths of the two approaches are contrasted in Figure 2-1.

Ammonia has been the chemical most used for  $\text{NO}_x$  reduction, but recent years have seen development of the use of related chemicals (e.g., urea and cyanuric acid). Ammonia and urea have both been used in SNCR and SCR processes, but the temperature window of their application for SNCR is too high to be useful with diesel exhausts. The use of urea in SCR processes is a rather recent development and offers significant advantages over that of ammonia. SCR (urea) provides at least the  $\text{NO}_x$  reduction that SCR ( $\text{NH}_3$ ) provides (both >90 percent), but without the burden of being either a hazardous chemical or an environmental threat. The use of SCR (urea) was developed in Europe and is currently available only from European suppliers. Cyanuric acid has been used for SNCR (non-catalytic) processes. Its major claim is that it is more effective than either ammonia or urea at the lower temperatures characteristic of diesel exhausts.

## **2.2 $\text{NO}_x$ Reduction From EMD 645 Dual-Fuel Engines**

Several efforts have been undertaken to use natural gas with 2-stroke diesel engines. Those of interest to the MUSE engine generator program are summarized in Table 2-1. The first line provides operating data from current MUSE EMD 645 diesel engines as a baseline for comparison. The remaining cases are for engines from the same locomotive-type engine series (the EMD's 567, 645, and 710, cylinder displacement in cubic inches) and the Detroit Diesel 92 (a truck-sized engine). Fuel type is either dual fuel (DF) or natural gas (NG), and charging of the engine cylinders with natural gas is described as either early or late in the compression stroke. For early injection (EI), a low injection pressure (100 to 300 psi) can be used. Air flow and mixing patterns within the cylinder then produce a nearly homogeneous fuel/air mixture prior to ignition. For late cycle injection (LCI), a much higher pressure (>3,000 psi) is required, and as pre-mixing of the fuel and air is not achieved prior to ignition, a diesel-type combustion takes place. Ignition of the natural gas charge in both of these cases is by injection of a pilot quantity of diesel fuel (4 to 7 percent of the amount required for full diesel operation) into the cylinder at the time of ignition. Significant  $\text{NO}_x$  reduction is achieved with the EI process.  $\text{NO}_x$  reduction is much more difficult to achieve for the LCI process.

Anticipated advantages of LCI are increased engine thermal efficiency (a higher compression ratio diesel cycle can be used) and avoidance of the combustion "knock" that limits power production in Otto cycle (homogeneous combustion) engines. Disadvantages of LCI are the technical problems and high cost of providing natural gas at pressures greater than 3,000 psi and the difficulty in achieving reduced  $\text{NO}_x$  emissions in higher-pressure, higher-temperature combustion environments. The advantage of reduced fuel costs due to the use of natural gas rather than diesel fuel is provided by both approaches.

The data of Case 1 were obtained in 1982 from a locomotive engine fueled from compressed natural gas cylinders carried on a railroad flatcar (Ref 2-4). The major limitation observed in that test operation was the reduction (20 to 30 percent) of available engine power

caused by the onset of combustion knocking. In Case 2, the Department of Energy (DOE) sponsored single-cylinder engine tests (Refs 2-5 and 2-6) to determine if improved engine thermal efficiencies and power production could be obtained with a diesel-type (late cycle injection) combustion process for dual fuel operation. Although substantial progress was made in these tests, engine efficiency and exhaust emission objectives were not achieved. The DD 92 spark-ignited, truck-sized engine (Case 3) had significantly different requirements than those for the larger locomotive engines. Its manufacture was discontinued after several years' production.

Case 4 was undertaken by many of the same parties involved in Case 1, but with several changes. These included: using turbocharging rather than positive displacement compressors for charge-air compression; changing the piston crown design to improve fuel-air mixing and to reduce the compression from 14.5 to 12.8; altering the head configuration to allow admission of natural gas into the chamber using electronic rather than mechanical controls; incorporating additional charge-air cooling for the engine; modifying the controls of the injector rack; and incorporating single-bank engine idling to reduce emissions and improve engine efficiency (Ref 2-7). The results achieved were sufficient to convince the Burlington and Northern Railway to install retro-fit packages designed, specifically, for the EMD 645 engine on two tandem locomotives for coal line-haul operations between Montana and Wisconsin. Liquefied natural gas (LNG) was used as the fuel, and a separate LNG fuel car was constructed to provide fuel. An LNG refueling station for the round trip was provided in Minnesota. The performance, reliability, and emissions reduction of that technology were demonstrated in a program that continued for over two years. The technology represented by this demonstration test appears to be the only engine-related retro-fit technology available for achieving significant  $\text{NO}_x$  reductions with the EMD 645 engine.

The last entry in Table 2-1 is for development tests that have been underway at the Southwest Research Institute (SwRI) for development of the late, high-pressure injection of natural gas. Data regarding the performance, emissions, cost, and reliability of this technology have not yet been published.

### **2.3 Further Reduction of $\text{NO}_x$ Emissions**

Although the 70 percent reduction in  $\text{NO}_x$  demonstrated by the results of Case 4 is an important step forward, further  $\text{NO}_x$  reductions appear to be available with some additional modification of the dual-fuel EMD 645 engine. These have centered on the use of pre-ignition chambers and/or separate diesel injection igniters (see Table 2-2). The results presented in this table show that  $\text{NO}_x$  emissions for dual fuel injection can be reduced to the level of 1.0 gram/hph while the required pilot fuel is reduced to about 1.0 percent (Reference 2-8 and 2-9 indicate that CO, hydrocarbon, and particulate emission are also significantly reduced.). Although the use of pre-chambers in engines is a familiar concept, their use with dual fuel engines has been limited and their significant advantages have not been widely explored. In the cases shown, the Wartsilla is a somewhat complex multi-fueled application requiring high pressure injection (Ref 2-10). It would not be useful for Navy MUSE units. Cooper Bessemer (Cases 2 through 5) conducted tests that started with the objective of improving the operation of large spark-ignited natural gas engines and resulted in major improvements in their dual fuel engines as well (see Fig. 2-2, Ref 2-8). The Cooper Bessemer engines were all four-stroke units. Fairbanks-Morse (Ref 2-9) achieved results similar to those of Cooper Bessemer with a 900-rpm, two-stroke,

opposed-piston engine. A plan view of the injector arrangement for the natural gas, diesel, and pre-chamber injectors of the Fairbanks Morse application is shown on Fig. 2-3. When the engine is operating in the diesel mode, both diesel injectors are used. In the natural gas mode, a single, low-pressure gas injector is used along with a diesel-fired pre-ignition chamber. Figure 2-4 shows Fairbanks-Morse data for four modes of engine operation: standard diesel, standard dual fuel, spark ignition, and Enviro Design pre-chamber. The numbers within each region of the figure refer to the number of data points used to define that region,  $\text{NO}_x$  emissions and thermal efficiency (brake-specific fuel consumption) are significantly superior for the Enviro-Design.

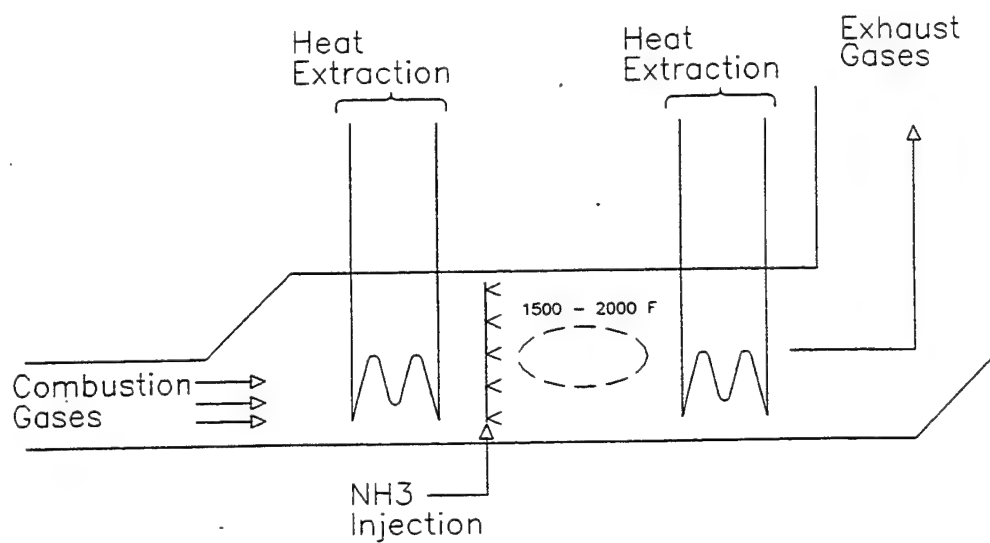
Pre-chamber parameters affecting the reliability and effectiveness for achieving ignition, minimum emissions, and minimum pilot fuel are shown on Figure 2-5 (Ref 2-8).

Combustion pre-chambers can be used with dual fuel engines to:

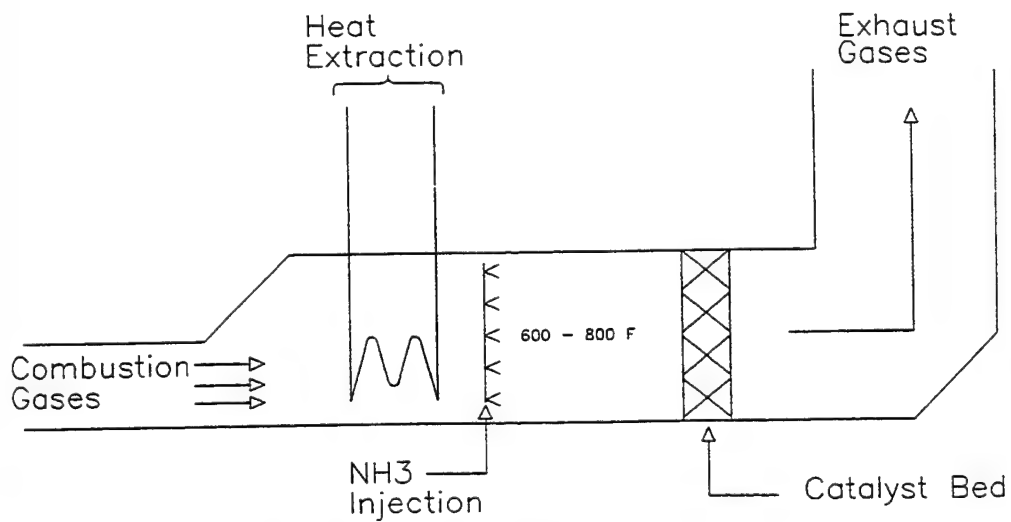
- Further lower  $\text{NO}_x$ , hydrocarbon, CO, and particulate emissions.
- Improve engine thermal efficiency.
- Reduce the required diesel pilot fuel for both two- and four-stroke dual fuel engines.

This technology is now available and could be applied to the EMD-645 to achieve further important improvements in exhaust emissions and thermal efficiency for dual fuel operation. Such efforts would require a modest extension of the existing dual fuel technology (low-pressure injection) already demonstrated on B&N RR locomotives and the Navy MUSE unit. Successful demonstration of a dual fuel EMD-645 engine with pilot ignition would bring the Navy's stationary dual fuel units to the level of  $\text{NO}_x$  required by the most restrictive emissions regulations in the country for stationary engines.





(a) Selective non-catalytic reduction (SNCR).



(b) Selective catalytic reduction (SCR).

Figure 2-1. General features of SCR and SNCR NO<sub>x</sub> reduction processes.

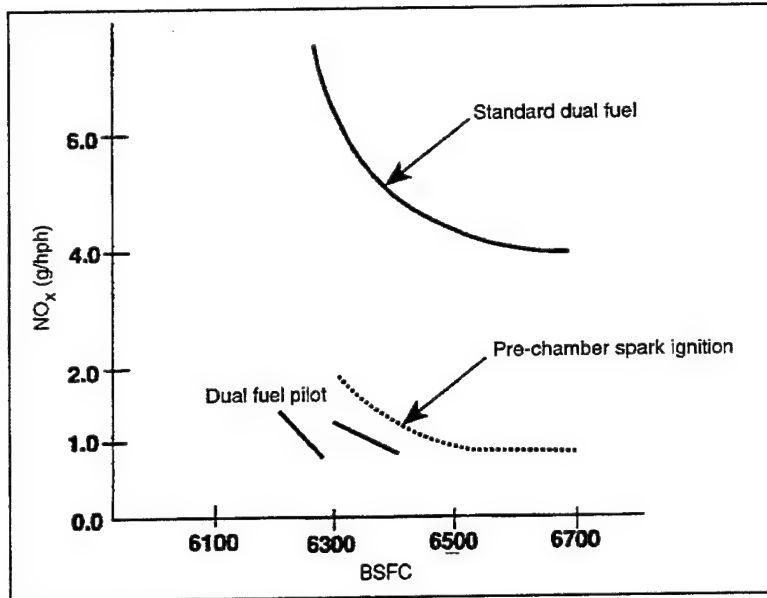


Figure 2-2. Results of tests conducted by Cooper Bessemer showing NO<sub>x</sub>

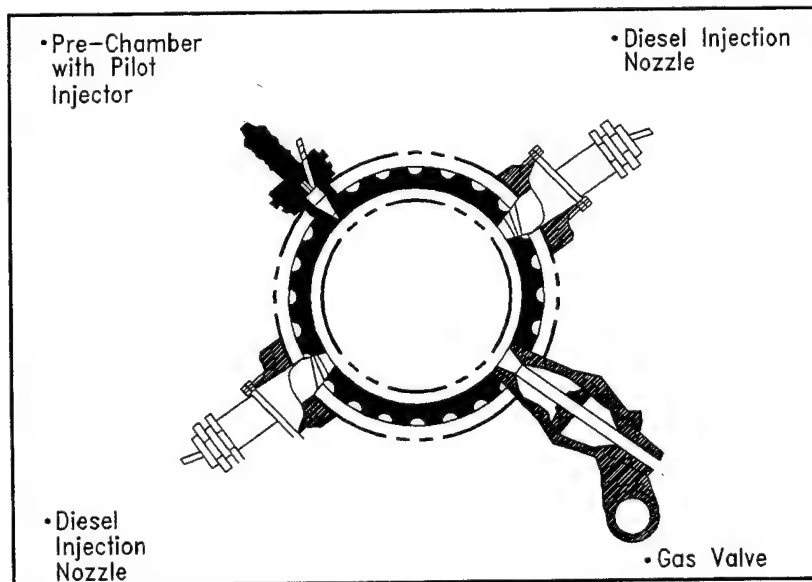


Figure 2-3. Plan view of arrangement of natural gas, diesel, and pre-chamber injection for Fairbanks-Morse application.



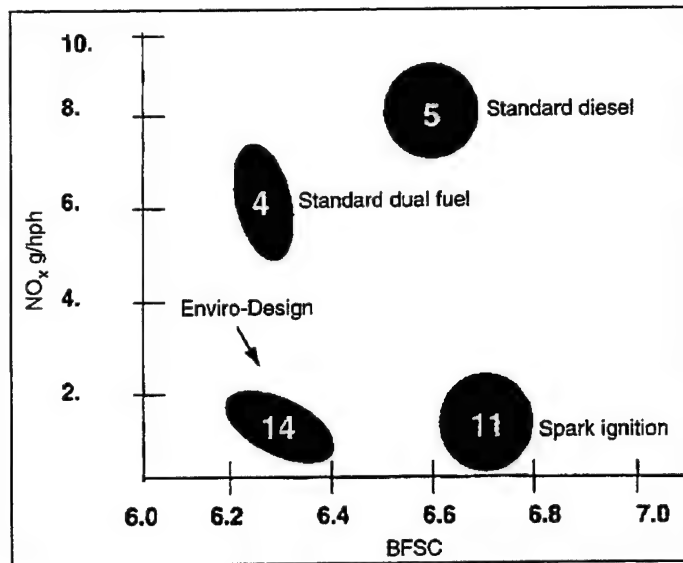


Figure 2-4. Results of tests conducted by Fairbanks-Morse showing NO<sub>x</sub> emissions and brake specific fuel consumption (Btu/hph).

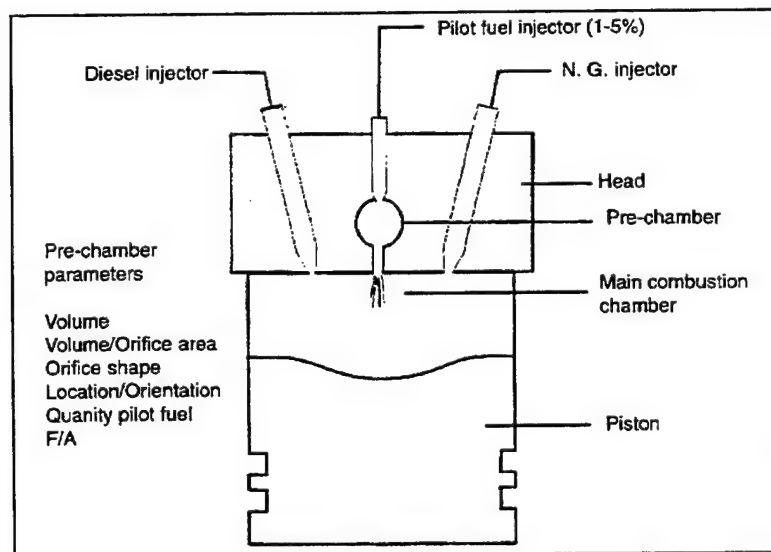


Figure 2-5. Schematic outline of dual fuel cylinder and parameters that affect pre-chamber performance.

Table 2-1. NO<sub>x</sub> Reduction Technologies Related to EMD-645

Case	Mfgr	Number Strokes	Fuel Type*	Natural Gas Injection		Pilot Diesel		NO <sub>x</sub> g/hph	Other
				Time	Pressure	%	Location		
1	EMD-567	2	DF	Early	200	7	Main	---	Low power, 1982
2	EMD-567	2	DF	Late	3,500	2.0 knock limit	Main, side wall	5	Heavy smoke, reduced efficiency SwRI**
3	Detroit Diesel 92	2	NG	Early	250	N/A	N/A	N/A	Discont'd production
4	EMD-645	2	DF	Early	100	6	Main	4	Full power locomotive, 1992-1995
5	EMD-710	2	DF	Late	High	?	Main	?	Results not available

\*DF = Dual Fuel, NG = Natural Gas.

\*\*Southwest Research Institute, Inc.

Table 2-2. Further NO<sub>x</sub> Reductions Using Pre-Ignition Chambers

Mfgr	Number Strokes	Fuel Type*	Natural Gas Injection		Pilot Diesel		NO <sub>x</sub> g/hph	Other
			Time	Pressure (psig)	%	Location		
Wartsilla	4	MF	Late	4,000	5	Main	5	New and Retrofit
Cooper Bessemer	4	NG	Early	Low	Spark	Pre-	1.5	Std for DF
Cooper Bessemer	4	DF	Early	Low	5	Main	5	Optimized
Cooper Bessemer	4	DF	Early	Low	1	Main	4	Unstable combustion
Cooper Bessemer	4	DF	Early	Low	0.9	Pre-	1	Full power, improved opacity
Fairbanks-Morse Enviro Op	2	DF	Early	Low	---	Main	4.5	---
Fairbanks-Morse Enviro Op	2	DF	Early	Low	1.4	Pre-	1	Full power

\*MF = Multi-fuel, NG = Natural Gas, DF = Dual fuel.

### 3.0 ELEMENTS OF THE ECI/EMD DUAL-FUEL CONVERSION

The EMD 645 two-stroke engine has 8 to 20 cylinders, is of 45-degree V construction, uses a turbocharger to pressurize the air supply, and has direct diesel fuel injection. It has 4 exhaust valves in each cylinder head and receives its combustion air through ports in the cylinder liner (Fig. 3-1). When converted to dual fuel operation, natural gas is admitted into the cylinder by a gas inlet valve (GIV) with direct access to the combustion chamber (Fig. 3-2).

#### 3.1 Natural Gas Fuel

Natural gas is composed principally of methane ( $\text{CH}_4$ ), with smaller quantities of other hydrocarbons, carbon dioxide, water, and other species. The composition of a typical pipeline natural gas is given in Table 3.1. The non-methane hydrocarbons are often referred to as "heavy ends;" the multiple carbon atoms in their molecules providing both increased molecular weight and additional combustion energy because of the greater number of atomic bonds present in a given volume of gas. The heavy ends contribute more energy (BTUs) per volume of gas than does pure methane, but do not, necessarily, provide for better engine operation. Natural gas with a composition of methane and heavy ends that has a heat content greater than 1,100 BTU per standard cubic foot (SCF) is known as a "hot gas" that can lead to destructive engine knocking.

Methane is a high octane (130) fuel that exhibits excellent antiknock characteristics when used in spark-ignited engines. However, fuel characteristics that are good for spark-ignited engines are often undesirable for compression-ignited engines. The latter require high compression ratios to heat the air in the cylinder to the point that the fuel will spontaneously ignite upon injection. When natural gas is used as the fuel a compression ratio enabling the natural gas to spontaneously ignite would be significantly greater than that required for diesel fuel and would be too high to maintain reliable engine operation and performance. Therefore other approaches for igniting the natural gas/air charge must be used.

#### 3.2 Dual Fuel Characteristics

The solution adopted by ECI for igniting the premixed gas/air mixture in each cylinder is to use a small quantity of diesel fuel as a pilot charge to initiate combustion. Air is admitted to the cylinder at the bottom of the piston stroke and natural gas is then injected at low cylinder pressure. As the piston rises to the top of its compression stroke the gas/air charge is adiabatically heated. The diesel pilot fuel is then injected and the diesel fuel, with its lower ignition temperature, ignites and sets in motion a flame front through the gas/air mixture. Combustion chamber temperatures and pressures increase as the combustion front proceeds from the point of diesel injection. If the pressure becomes too great, autoignition can be triggered within the unburned air/gas mixture ahead of the flame front. When severe, this autoignition becomes destructive knock, and is aggravated when "hot gases" are used. To counteract this potential problem when burning natural gas in the EMD engine, ECI reduced the compression ratio of the engine from 14.5 to 12.8.

Although a lower compression ratio usually leads to lower engine power and efficiency, ECI redesigned the piston crowns and cylinder heads of the EMD 645 to minimize efficiency losses. It also added an auxiliary water-cooling circuit for the turbo-charger aftercooler to reduce air charge temperatures to the cylinders. These changes enabled the converted dual fuel engine to produce full diesel-rated horsepower in both dual fuel and diesels mode of operation in the locomotive application. Although the thermal efficiency for dual fuel operation is reduced several per cent from that obtained for full diesel operation, the savings in using natural gas more than compensates for this reduced efficiency and usually produces significant fuel savings.

Other than being a convenient method for initiating combustion, the dual fuel approach offers the advantage of a backup fuel system when natural gas is either not available or if a problem should arise in the gas system. This is an especially important consideration for Navy MUSE units. On the occurrence of a hazardous situation or engine malfunction while operating on natural gas, the ECI dual fuel system, controlled by the engine control unit (ECU), automatically shuts off the natural gas supply and, on-line, switches the engine to full diesel operation.

Natural gas in the ECI conversion is delivered to the cylinders at low pressure (100 to 200 psig). This involves admission of the natural gas into the combustion chamber when the piston is near the bottom of its travel and when chamber pressure is low. (High pressure injection (3,000 psig) entails forcing the gas into the already-compressed air along with the pilot fuel near the top of the piston stroke.) The major advantages of the low pressure injection system used by ECI are improved safety, material, and construction concerns, the opportunity to use less exotic, precision hardware than that required to handle and inject the low-lubricity natural gas at 3,000 psi, the avoidance of a fuel energy penalty for compressing the natural gas to 3,000 psi, and greater NO<sub>x</sub> reduction. High pressure injection systems would provide some advantage of increased horsepower and thermal efficiency, but the results of the development of that approach are not yet available.

### 3.3 Engine Operating Sequence

Dual fuel operation of the EMD engine can be divided into four phases: exhaust scavenging and air charging; gas admission, gas/air mixing and compression; ignition; and power production. These phases are described below and illustrated by the piston positions shown on Figure 3-2:

1. The piston is at the bottom of its stroke, starting up. The exhaust valves are open and the inlet air ports in the liner are uncovered. Compressed air (from the turbocharger at about 17 psig) is forced from the air box that surrounds each cylinder into and through each cylinder, displacing the exhaust gases from the previous power stroke out through the exhaust valves and into the exhaust system.
2. Admission of natural gas into the cylinder begins with the GIV opening after the cylinder has been recharged with fresh air and after the exhaust valves have closed. The quantity of fuel gas charged to the cylinder is controlled by a Gas Flow Control Valve (GFCV) and the time of opening of the GIV, both of which are controlled by the Engine Control Unit (ECU). The discharge of the gas into the cylinder under

pressure along with the air motion established by the recharging of the air provides fluid motion for mixing the fuel and air charges. The upward movement of the piston further enhances the mixing and compresses the air/gas charge to a temperature sufficient for ignition of the diesel pilot fuel.

3. Just prior to the arrival of the piston at top-dead center (TDC) a small amount of diesel pilot fuel is sprayed into the cylinder by the diesel injector. The pilot fuel is ignited by the hot gases and, in turn, serves as an ignition source for the natural gas/air mixture that is now nearly homogeneously mixed.
4. The fuel/air mixture burns, increasing the temperature and pressure within the cylinder and driving the piston down during the power stroke.
5. The exhaust valves open as the piston passes 106° after TDC to allow the exhaust gases to escape the power assembly, and the inlet air ports open at 135° to allow the charging air to scavenge the exhaust gases and to replace them with a fresh air charge. The piston continues to BDC where the cycle repeats itself.

### 3.4 Conversion Kit Components

The ECI conversion kit converts the standard EMD diesel engine to dual fuel operation by replacing the pistons and heads, adding gas handling and gas injection hardware, and installing modified aftercoolers and other supporting hardware and instrumentation.

**3.4.1 Duel Fuel Heads and Pistons.** The ECI dual fuel head is similar to the standard EMD diesel head with the exception of an additional opening through its top that directly accesses the combustion chamber. This opening accepts the gas inlet valve.

Piston head modifications are made to ensure proper gas/air mixing and to lower the compression ratio to 12.9. The shape of the top of the piston enhances swirl and promotes combustion of the gaseous fuel. At idle, the engine runs 100 percent on diesel using the ECI-developed Low Emission Idle (LEI) method that alternates engine banks to improve efficiency and reduce emissions.

**3.4.2 Gas Inlet Valves.** The Gas Inlet Valve is a microprocessor controlled, electrically-actuated, pneumatically-driven poppet valve. The GIVs have advantages over mechanically-actuated valves in that they can be software-tuned for various engine speeds and conditions without changing the camshaft. The gas inlet valves are modular components that are unit replaceable, similar to the diesel injector. They remain closed when the engine is not running on gas to preserve their life and reliability and to prevent combustion by-products from building up on the GIV's valve stem.

**3.4.3 Pilot Fuel Control and Diesel Injection.** The standard diesel fuel injectors are recalibrated to a pilot level. This slightly alters the fuel output at full diesel throttle, although full horsepower is still available when running in the diesel mode. The converted engine starts and

idles on diesel and automatically begins gas operation after the engine reaches operating temperature and a preset speed (880 RPM) and an engine loading of 300 kW. On shutdown, the diesel-to-gas operational transfer occurs at an engine loading of 55 kW, just prior to opening the breaker at 50 kW.

The fuel injection system is designed to make it possible to run equally well on full diesel or on natural gas. The pilot fuel control system employs an electronically controlled mechanism that is attached to the governor/fuel rack linkage. During gas operation the device overrides the diesel governor permitting only a small pilot quantity of diesel to be injected into the cylinder. During diesel operation, the device relinquishes control to the governor, which then provides conventional diesel operation.

**3.4.4 Low Emission Idle (LEI).** Low Emission Idle (LEI) runs the engine on eight of its sixteen cylinders when the engine is idling. The additional load the non-firing cylinders places on the engine causes the firing cylinders to burn the diesel fuel completely, producing a fuel savings of approximately 15 percent and significantly reducing unburned hydrocarbons in the exhaust. An electronic timer in the air control cabinet controls switching between the engine banks. (Note: The current Navy unit does not include this option as Navy engines do not, normally, have extended periods of idling. This option could be included, however, if smoking at idling, when diesel fuel is being used, is perceived to be a problem.)

**3.4.5 Electronic Control Unit.** The patent for the engine control method was purchased by the ECI partnership in 1984. Using copyrighted software developed in-house, the ECU controls critical engine functions and safety systems. It is designed to, on-line, switch the engine to full diesel operation in the event of an irregularity in gas operation.

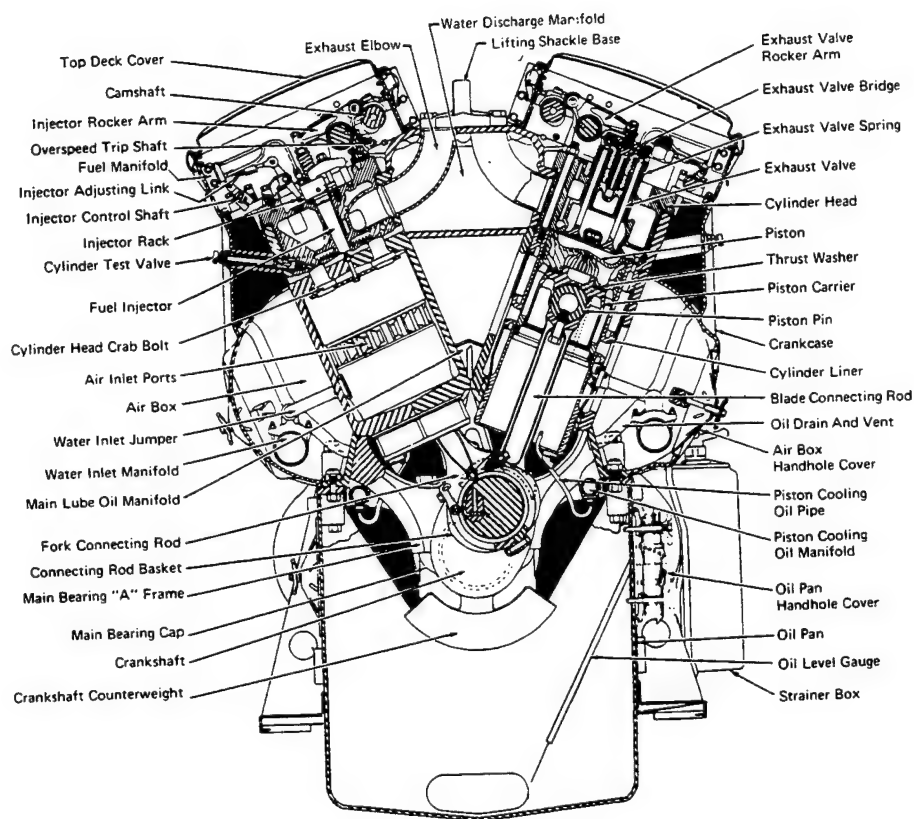


Figure 3-1. Cross section of EMD engine.

(Used by permission, Energy Conversions, Inc., U.S.A., 1996.)

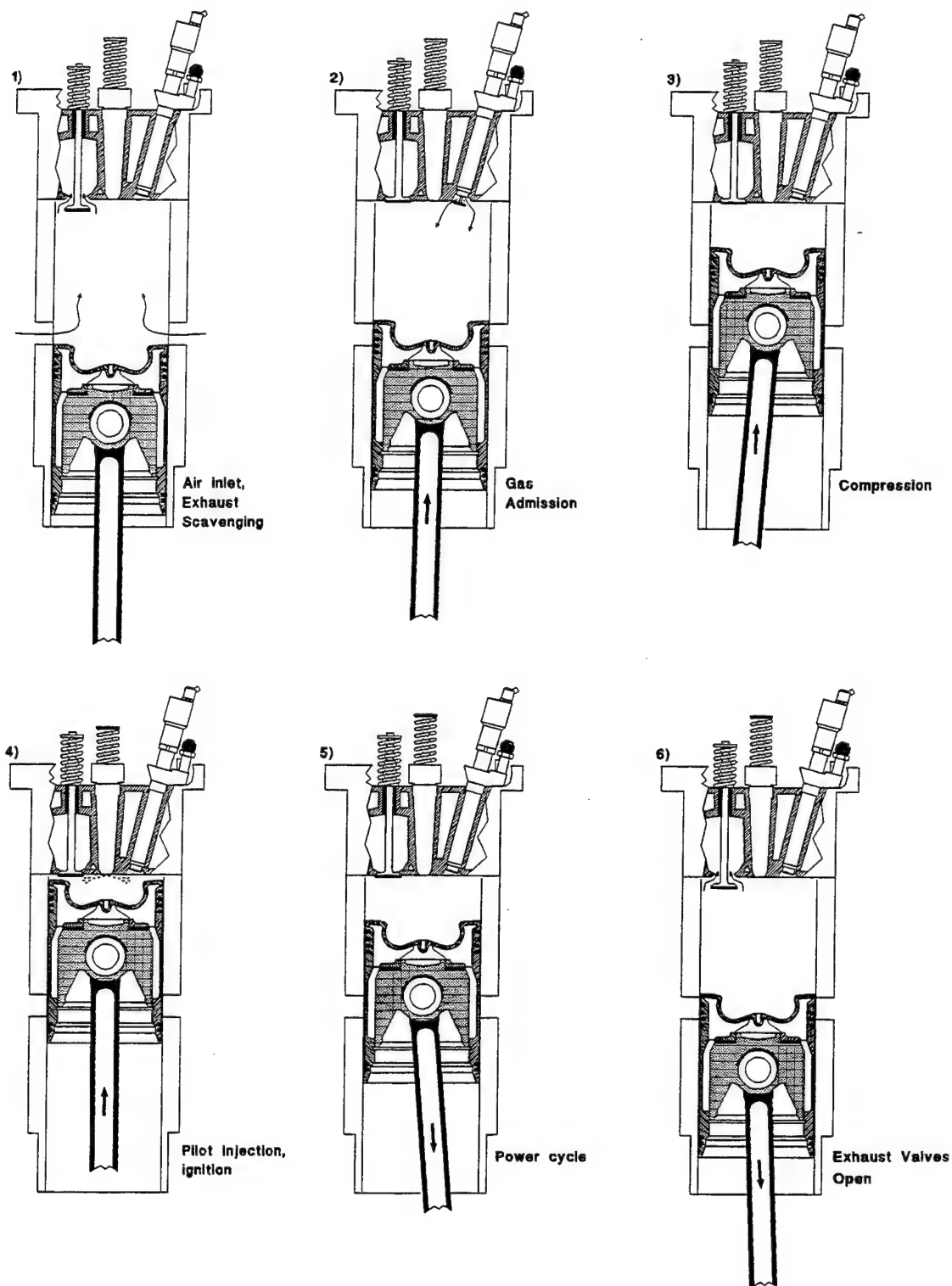


Figure 3-2. Dual-fuel EMD 645 engine operating phases.  
*(Used by permission, Energy Conversions, Inc., U.S.A., 1996)*



Table 3-1. Typical Natural Gas Composition

Component	Molar Percentage
Nitrogen	0.323
Carbon Dioxide	0.174
Methane	92.241
Ethane	6.500
Propane	0.551
Iso Butane	0.042
N Butane	0.055
Hexanes +	0.045
Oxygen	0.069
Btu/cu ft.	1,071.000

## 4.0 SUB-SYSTEM DESCRIPTIONS AND INSTALLATION PROCEDURES

The modification of the MUSE 1,500-kW engine generator set to dual fuel operation is described as a series of systems, each consisting of components connected by electrical circuitry, mechanical or electrical conduits, and/or other mechanical linkages. The actual modification hardware and procedures are described in References 4-1, 4-2, and 4-3 that have been assembled by ECI, Inc., based on the Navy's prototype application for stationary power. The use of those publications is essential to the proper installation of this dual fuel kit. This section draws heavily on them, and supplements them with information specific to the Navy MUSE unit. The description of each system includes schematics, detailed drawings, and photographs of the installation and installation process.

### 4.1 Engine Modifications

**4.1.1 Power Pack Assembly.** The dual fuel power pack assembly is shown on Figure 4-1. Included in it is the head, modified to receive the gas injection valve (GIV), the dual fuel piston, whose top surface has been modified to lower the compression ratio from 14.5 to 12.8 and to provide a greater intensity of mixing of the natural gas and air, and natural gas connecting hardware that includes the load valve, load block, gas and air lines and the GIV. Although the heads and pistons are changed as noted and the ring sets are special parts, the power pack assembly procedure is identical to that of the standard diesel power pack. Figures 4-2(a) through 4-2(d) show the placement of the GIV into the cylinder head with attachment of the natural gas supply and control air hoses.

**4.1.2 Cylinder Relief Valves.** ECI cylinder pressure relief valves (Fig. 4-3) are used to replace the standard cylinder test valves. These valves are located at each cylinder just under the natural gas supply line to relieve excess pressures that can arise during gas operation.

**4.1.3 Diesel Fuel Supply.** The original diesel fuel system is modified to provide "pilot" fueling capability during natural gas operation. Standard diesel injectors are used, but require special calibration to provide the correct "pilot" fuel quantities. Modifications also include the addition of a pilot fuel stop assembly mounted by the injector rack control linkage, and a system of air rams. The pilot stops are actuated with control air pressure through solenoid valves controlled by the Engine Control Unit (ECU). During higher loads the left-hand ram is extended. If the load drops below 20 percent, the second ram is energized increasing the pilot fuel and stabilizing combustion at the light load. Figure 4-4 shows elements of the pilot fuel stop assembly and the modified injector control rack linkage. Figure 4-5 shows photographs of engine modification components.

## 4.2 Natural Gas Supply System

Figures 4-6 is a schematic diagram showing installation of the gas lines within the engine house leading from the engine cylinders to the external natural gas (NG) supply and control components leaving the engine house. Figure 4-8 shows photographs of the NG piping, fittings, and their installations.

Under normal operation, natural gas is used within the unit at pressures of 100 to 150 psi. The pressure, normally, must be reduced from a higher supply pressure and closely regulated to the desired level. The gas, first, passes through a master manual shutoff valve followed by the pressure regulator. It then passes through two air-operated shutoff valves and a piping tee that leads to a pressure relief valve (set at 150 psi), a filter, an air-operated vent valve, and on to the NG piping in the interior of the engine house. There it passes through an instrumentation run (Fig. 4-9) where the gas temperature, pressure, and the flow rate are measured, to a third air-actuated gas cutoff valve (GCOV, Fig. 4-10), and on to the gas flow control valve (GFCV).

When the ECU determines that it is time for gas operation, valves V1, V2, and GCOV are opened for a brief period of time (5 seconds) to charge the natural gas supply line. At that point, the V1 and V2 are closed and the pressure of the natural gas in the line downstream of them is monitored for 180 seconds to ensure that the pressure remains constant and that no significant leaks are present in the gas supply line (a pressure loss of less than 3.0 psi must be observed for the system to pass this test). If the gas line does not pass the integrity test, it is vented to atmospheric pressure (through a vent valve, located on the gas flow control valve (GFCV), Fig. 4-10), and on to the exterior vent pipe). V1 and V2 remain closed, and the engine is prevented from proceeding to NG operation. If the gas line passes the integrity test, valves V1 and V2 are opened, providing a NG supply up to the GCOV. At that point, the ECU opens the GCOV and starts to sequentially open the GIVs to each of the cylinders to provide a flow of NG to them. The gas flowrate to the engine is controlled by the GFCV (Fig. 4-11), the position of which is determined by a direct mechanical linkage from the output shaft of the Woodward governor (the standard diesel component for governing engine speed and load).

From the GFCV the gas makes its way through the headers (Fig. 4-12) to each load block and GIV. Each load block has a restrictor valve that can be adjusted to either increase or decrease the gas flow to each cylinder to balance the power that is delivered. The gas pressure in the header, controlled by the GFCV, changes with load over a range of 25 to 65 psi. In switching to diesel operation, the GCOV, V1 and V2 all close. The GIV's cease to operate shortly thereafter, leaving some NG in the header. This gas is immediately vented via the vent valves on the GFCV and on the NG supply line external to the unit so that no natural gas lines within the engine skid remain pressurized at any time except when the engine is operating on it.

## 4.3 Control Air System

Most working parts of the conversion are pneumatically actuated and require a reliable source of compressed air. The largest single requirement for compressed air is for actuation of the GIVs. These require 15 SCFM so that a larger compressor (30 SCFM vs. the original 15 SCFM) with a similarly sized air storage tank (240 SCF at 225 psi) was installed on the MUSE unit (the compressor installation is described in Section 4.5). Air from the compressor first passes through a filter, regulator, and air lubricator (Fig. 4-13). One branch of the air line then

passes directly to the GIVs. Figures 4-14 and 4-15 show a pictorial of the air hose connections and details of the routing of the air to the GIVs. Item 2 of Figure 4-14 shows a second air supply line going to the Air Supply Cabinet (ASC) out of which air control hoses emanate to provide actuating air to: the diesel ram (item 3), the pilot fuel stop (item 4), the vent valve on the GFCV (item 5), and the GCOV (items 6 and 7). Items 8 through 11 indicate additional air hose routes are left to the installer to determine after the locations of the components connected by them are fixed. Details of the air supply tubing for the GIV's are shown on Figure 4-16, and the internal arrangement of the ASC is shown on Figure 4-17. A schematic diagram for the mounting bracket for the ESC and ASC is shown on Figure 4-18 and photographs of them mounted are provided on Figure 4-19.

#### **4.4 Air Throttle**

The air throttle is a device that is used to control the amount of combustion air available to the engine. It provides a means of operating the engine at increased efficiency at reduced loads and is located at the turbocharger inlet. Figure 4-20 compares the original turbocharger installation with that of the installation that includes the air throttle. Figure 4-21 provides photographs of the modified installation.

#### **4.5 Engine Cooling System**

The engine cooling system has been enhanced by adding a cooling water circuit to send part of cold water stream exiting the radiator directly to the inlet of the aftercoolers (Fig. 4-22). This is to provide greater cooling of the combustion air than is normally obtained and allows operation of the engine in the natural gas mode at increased power levels. The added water circuit requires the use of an aftercooler water pump, and to further enhance cooling of the combustion air, an ECI-designed 6-pass aftercooler is used to replace the standard 2-pass aftercooler. The new aftercoolers (Fig. 4-23) are designed so that counter flow is accomplished on both sides of the engine. The coolers are installed following the guidelines found in the EMD maintenance manual for the standard aftercoolers. A 140-gpm pump is used for the aftercooling circuit.

Installation of the new cooling water pump, along with the new air compressor, is shown on Figures 4-24 through 4-27. The original air compressor and air tank had to be replaced with ones of greater capacity and structural strength. A place to mount the water pump also had to be found. Therefore, a mounting plate capable of supporting both was designed. Figure 4-24a and 24b show the original air compressor mounting configuration and the final one with both air compressor and water pump installed. Figure 4-25 shows the support platform supported at four positions by the compressed air tank, by two channel iron leg supports mounted on the side I-beam of the unit, and by a fourth support leg. Figure 4-26 and 4-27 provide specifications for the compressed air tank and platform, the support legs, and the platform.

## 4.6 Sensors

Sensors are provided for a variety of measurements (Fig. 4-28). It is important that they operate properly. Out-of-specification measurements are warning signs indicating either engine malfunction or improperly functioning sensors. In either case, they may indicate dangerous or hazardous conditions and cause the engine to terminate operations. Figures 4-29 and 4-30 show the installation of several of the sensors described below.

**4.6.1 Thermocouples.** Thermocouples are fitted one per cylinder through the engine manifold. They are used to monitor the temperature of the exhaust gas coming from each cylinder as a primary indication of proper cylinder performance.

**4.6.2 Water Temperature.** A bad or partially failed sensor will be displayed by the ECU as an error.

**4.6.3 Control Air Pressure.** Control air is provided by the compressor at 200 to 240 psi. It is then reduced in pressure by the pressure regulator to the control range of 125 to 135 psi. Pressures more than 4 psi outside of this range cause the unit to shut down.

**4.6.4 Flywheel Sensors.** The flywheel sensor apparatus consists of three sensors mounted on a bracket over the flywheel, along with sensor targets. The two sensors provide timing information to the ECU. These are positioned to sense 1/4-inch targets embedded in the flywheel, and their output is used to synchronize the natural gas sequencer with the cam shaft for timing injection of natural gas into the cylinders. The third sensor is positioned directly over the teeth of the ring gear and uses the gear teeth as targets to determine flywheel speed.

**4.6.5 Air Box Temperature.** The air box temperature is monitored to sense temperatures that become too high ( $>200^{\circ}\text{F}$ ) and which can lead to engine knocking when operating in the natural gas mode.

**4.6.6 Air Box Pressure.** Air box pressure is an indication of turbocharger (TC) function. Low air box pressure ( $<14$  psi) indicates that the turbocharger is still probably being driven directly by the engine. Higher pressures ( $>17$  psi) indicate sufficient exhaust gases (at higher engine loads) to cause the TC to disengage from the engine and to be driven, solely, by the exhaust gases. The latter results in more efficient engine operation.

**4.6.7 Natural Gas Sensors.** These include the temperature and pressure sensors, the delta pressure sensor, and the delta pressure transducer. These monitor the condition of the natural gas upstream of the GFCV before being admitted to the gas header along with its flow rate to the engine.

**4.6.8 Gas Header Pressure.** The gas header pressure measures the pressure of the natural gas to the end of the header farthest from the supply. A minimum level must be maintained to continue engine operation. Excessive pressure indicates gas injector malfunction.

## 4.7 Natural Gas Safety System

Several approaches are used to ensure safe natural gas (NG) operation of the MUSE unit. These include both hardware additions and modifications and operational changes. Natural gas consists, mostly of methane, a colorless, odorless, non-toxic gas. The familiar "odor of gas" often smelled is not that of methane, but of small amounts of sulfur-containing compounds added, specifically to provide the pungent odor. This is a safety feature provided by all natural gas suppliers, the odor being noticeable at very small concentrations.

The main concern with natural gas is that when it is mixed with air at concentrations of between 5 and 15 percent of NG by volume, it forms a combustible mixture. If such a mixture should form in a space it would be subject to an explosion if confronted by an adequate ignition source. As all 110 volt electrical circuits (and many circuits of less voltage) provide ignition sources sufficient to initiate a natural gas explosion, and as many such circuits exist within the MUSE engine enclosure, the approach taken for ensuring a safe environment has been to ensure that the NG concentration within the engine space will never reach the level of an explosive concentration. This has involved ensuring adequate ventilation of the engine space along with the installation and operation of a gas detection system. The fact that NG is lighter than air and has a strong tendency to rise away from the source of any leak is helpful in achieving this objective.

Appendix A includes an analysis and recommended design modifications and operational procedures to ensure the safe operation of this dual fuel conversion. This study was undertaken by a fire safety consulting firm with particular expertise in the handling of natural gas within enclosed areas. The recommendations of that study were incorporated into the design and operating characteristics of this dual fuel conversion.

Figure 4-31 shows a cutaway side view of the MUSE unit indicating NG pipe routing and safety features included in that piping run, and Figure 4-32 is a plan view showing air flows within the engine compartment to prevent the accumulation of NG explosive concentrations. The venting rate of the compartment is such that even with a severed NG supply line, concentrations of NG within the engine compartment would not reach an explosive level, assuming that the exhaust blower is properly functioning. System interlocks prevent the entry of NG into the engine compartment (ECU controlled) unless the exhaust blower is shown to be operating, unless air flow gauges show that adequate venting is actually taking place, and unless the natural gas detection system shows the absence of any measurable concentrations of an explosive gas. The shutdown level is set at 10 percent of the LEL (lower explosive limit for NG). This allows for the presence of some hydrocarbon vapors from greases and oils within the unit but provides a conservative monitoring level for the presence of NG from any leaks in the NG system. Figures 4-33 and 4-34 show the installation of the NG sensors and connecting conduits and wiring.

## 4.8 Electrical System and Controls

A pictorial view of the main features of the electrical and control system is shown on Figure 4-35. The two main electrical/control cabinets are the engine control unit (ECU) and the air service cabinet (ASC). An analog termination box is also shown. The basic wiring scheme for the system is indicated on Figure 4-36 which shows 16 wiring runs, 12 of which (numbers 1,



3, 4, 5, 7, 10, 11, 12, 13, 14, 15, and 16) are contained within conduits (flex or hard). The number, size, and type of wires within each run are indicated and each wire carries an alphanumeric designation.

The wiring design is laid out in a manner so that wire harnesses, assembled at the factory, can be pulled through the conduits and attached to terminal strips. Conduits from the ECU lead to (a) the operating system status screen, (b) the analog termination box, and (c) the ASC. The conduit leading from the ECU to the ASC actually contains several distinct wire harnesses for: (a) GIV control for admission of natural gas to each cylinder, (b) control functions to the existing engine control panel (ECP) and the switchgear (SG) house, (c) the control harness solenoids within the ASC, (d) electrical signals to the ECP for actuating the water pump, and (e) for controlling and receiving signals from the gas detection system.

**4.8.1 Engine Control Unit.** The ECU controls all major functions of the dual fuel engine operating system. It is an electronic device, and consideration should be given to the ambient temperatures of its proposed location to prevent unnecessary overheating. Otherwise, its location may be at any place within the engine generator housing that is convenient for gathering the engine operating data and for exercising its control function.

Figure 4-37 provides a block diagram of the electrical control signals entering and leaving the ECU and Figure 4-38 shows the physical layout of the inside of the ECU. Wiring connections internal to the ECU are shown on Figure 4-39 and ECU digital inputs, analog inputs, digital outputs, and GIV outputs are shown on Figures 4-40 to 4-43. Schematic diagrams of the switchhouse connections and wire harnesses are shown on Figures 4-44 and 4-45. Terminal connections within the ASC and the analog termination box are shown on Figure 4-46. Additional drawings of wiring harnesses are shown on Figures 4-47 to 4-50.

**4.8.2 Air Service Cabinet and Engine Control Panel.** The internal components of the ASC are discussed in Section 4-3 and electrical wiring hookups were discussed in the subsection, above. Photographs of wiring within the ECU and ASC are shown on Figure 4-51. Photographs of the ECP modifications are shown on Figure 4-52.

**4.8.3 GIV Wire Harness.** The GIV wire harness leads from the ASC to the upper deck (under the valve cover) where it is divided into two segments for either side of the engine (Fig. 4-53). It has leads to each cylinder for both operating the solenoid valves to admit natural gas and for monitoring the temperature of each valve (valve temperature switch (VTS)).

## **4.9 Switchgear, External Power Hookups and External Communications**

All hardware electrically linking the diesel generator with the activity is located in the switchgear house. Interconnects between the engine house and the switchgear (Fig. 4-54) include, (a) the 3-phase 4,160-volt power-carrying conductors, (b) a 40-wire umbilical interconnecting cable for transmitting engine and electrical control data, and (c) a second umbilical containing 12 shielded triads (20-gauge) for communication between the ECU and remote sites and for electrical control of the NG sensors mounted in engine house by the hazardous gas control module mounted in the switchgear house. The second umbilical includes signal wire for five telephone connections. Two of these are for separate signals for starting and

stopping of the unit from a remote site. Two dedicated lines are used for this purpose to avoid the possibility of interrupted telephone service interfering with control of the unit. The three other lines are used for transmitting operating data to the remote site control center and to other off-base sites by modem. Interconnects between the switchgear house and the base are the power-carrying cables contained in 4-inch underground conduit and a telephone interconnecting cable carried by a 1-inch underground conduit.

Electrical wiring connections to and within the switchgear house are described in the schematic diagrams referred to in Section 4.10. Photographs of the switchgear installation are shown in Figure 4-55.

#### **4.10 Modification of MUSE Schematic Drawings**

The impact of the modifications discussed above on existing MUSE schematic drawings has been incorporated into those drawings as indicated in Appendix B. Such modified drawings have been identified by the designation DF (dual fuel) appended to the original drawing numbers.



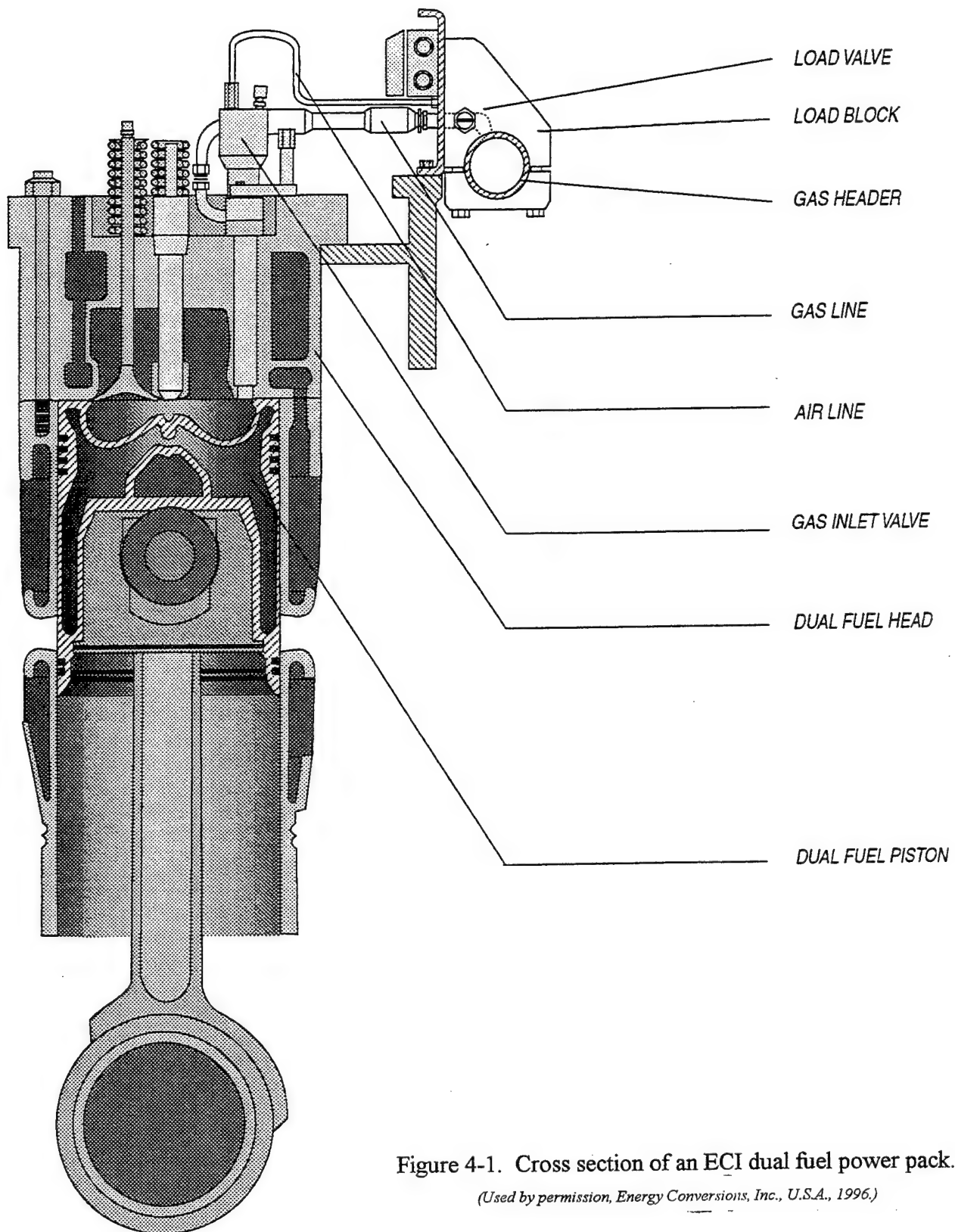
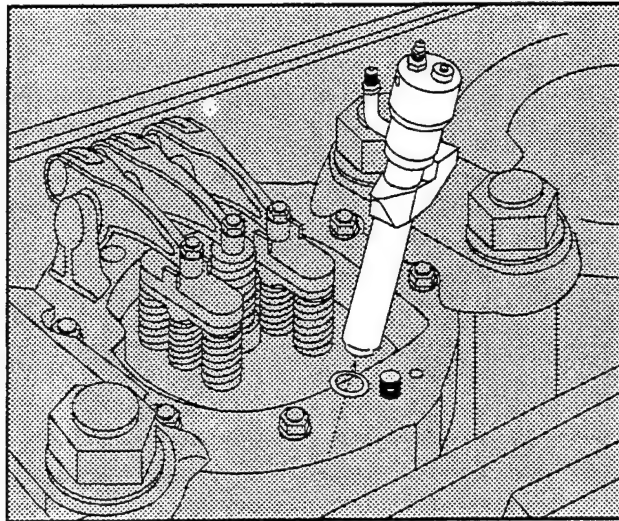


Figure 4-1. Cross section of an ECI dual fuel power pack.

*(Used by permission, Energy Conversions, Inc., U.S.A., 1996.)*

(a) GIV.



(b) GIV being installed.

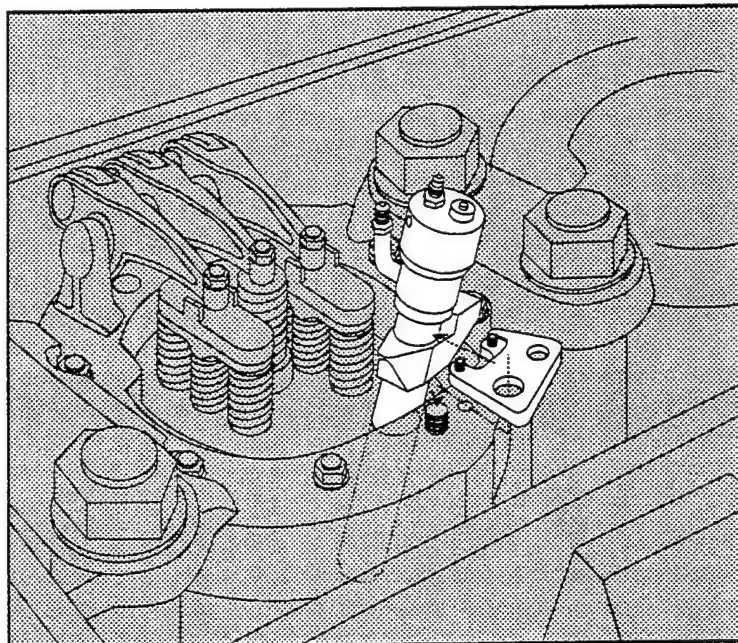
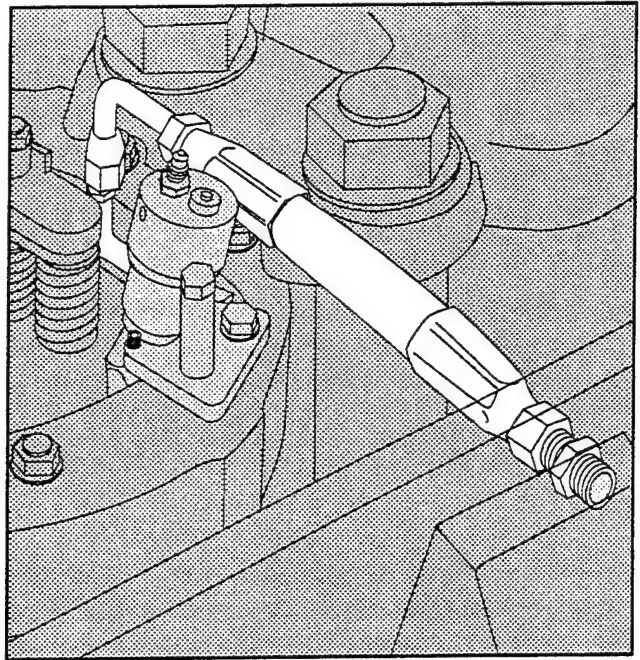


Figure 4-2. Installation of gas inlet valve (GIV) with natural gas and actuating air hoses.

*(Used by permission, Energy Conversions, Inc., U.S.A., 1996.)*

(c) Natural gas hose.



(d) Actuating air hose.

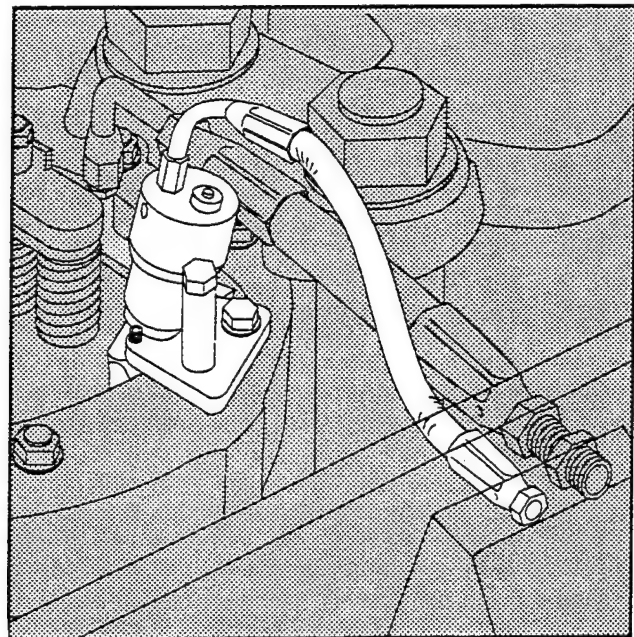
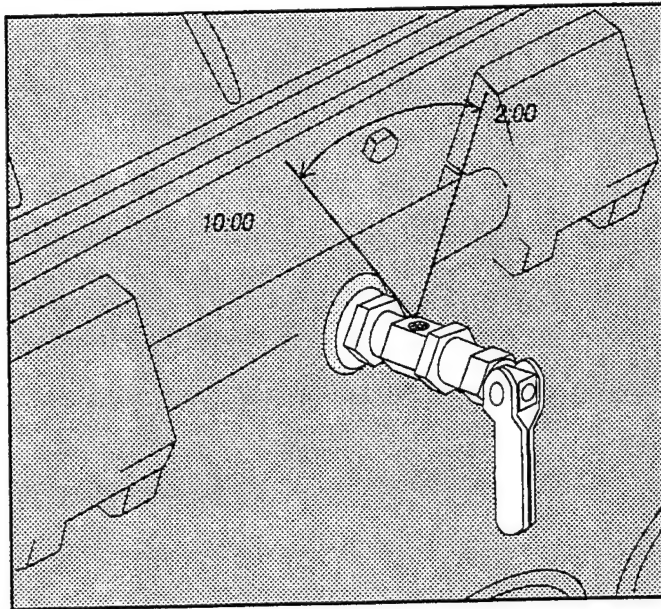
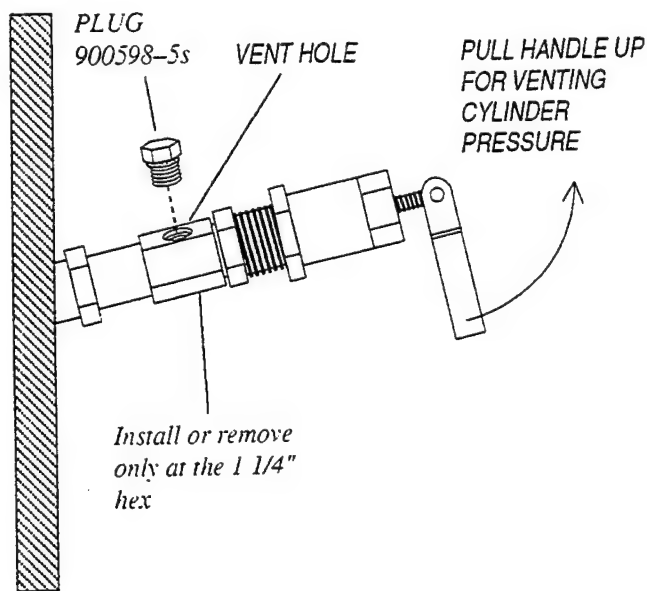


Figure 4-2. Installation of gas inlet valve (GIV) with natural gas and actuating air hoses. (Cont'd.)

*(Used by permission, Energy Conversions, Inc., U.S.A., 1996.)*



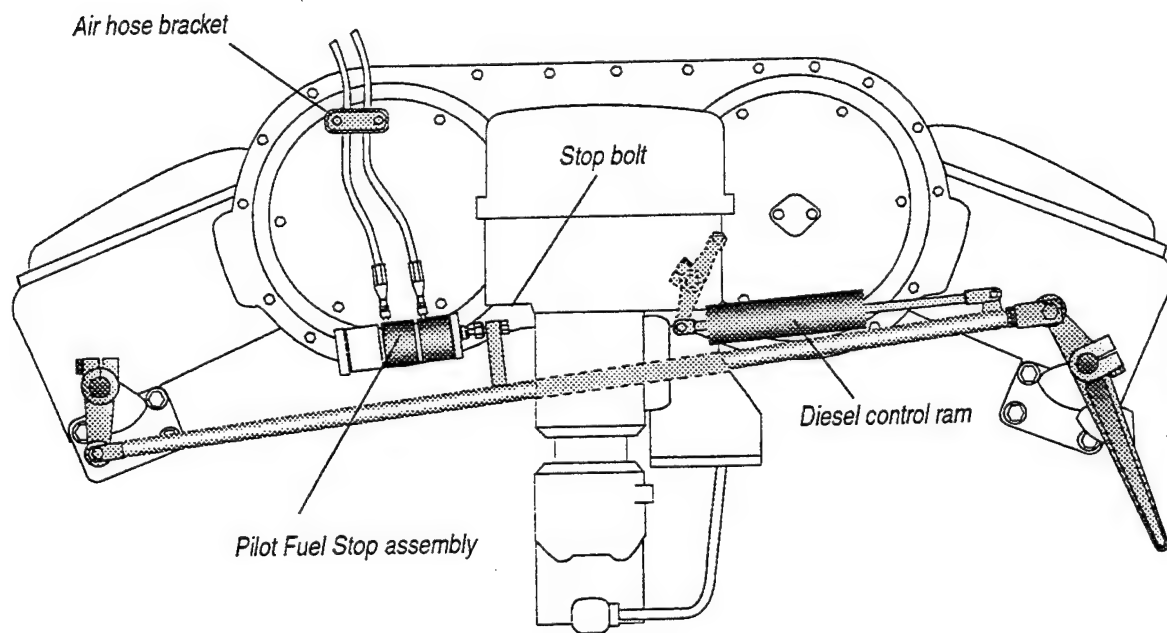
(a) In relation to NG header.



(b) Operating parts.

Figure 4-3. Installation of cylinder relief valve.

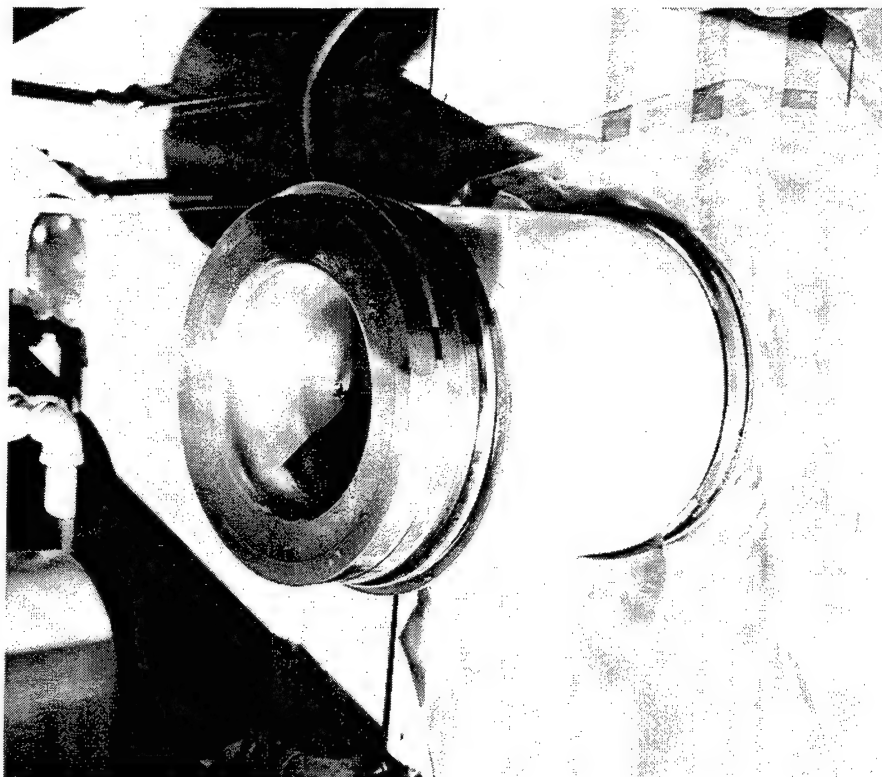
(Used by permission, Energy Conversions, Inc., U.S.A., 1996.)



**Figure 4-4. Pilot fuel stop assembly installed.**  
(Used by permission, Energy Conversions, Inc., U.S.A., 1996.)



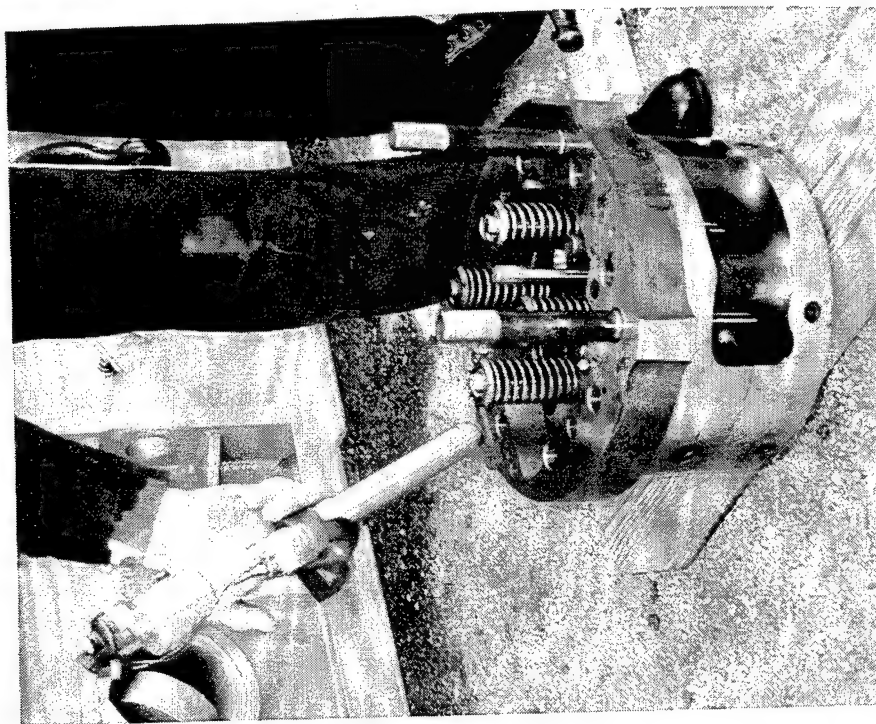
(a) Original piston.



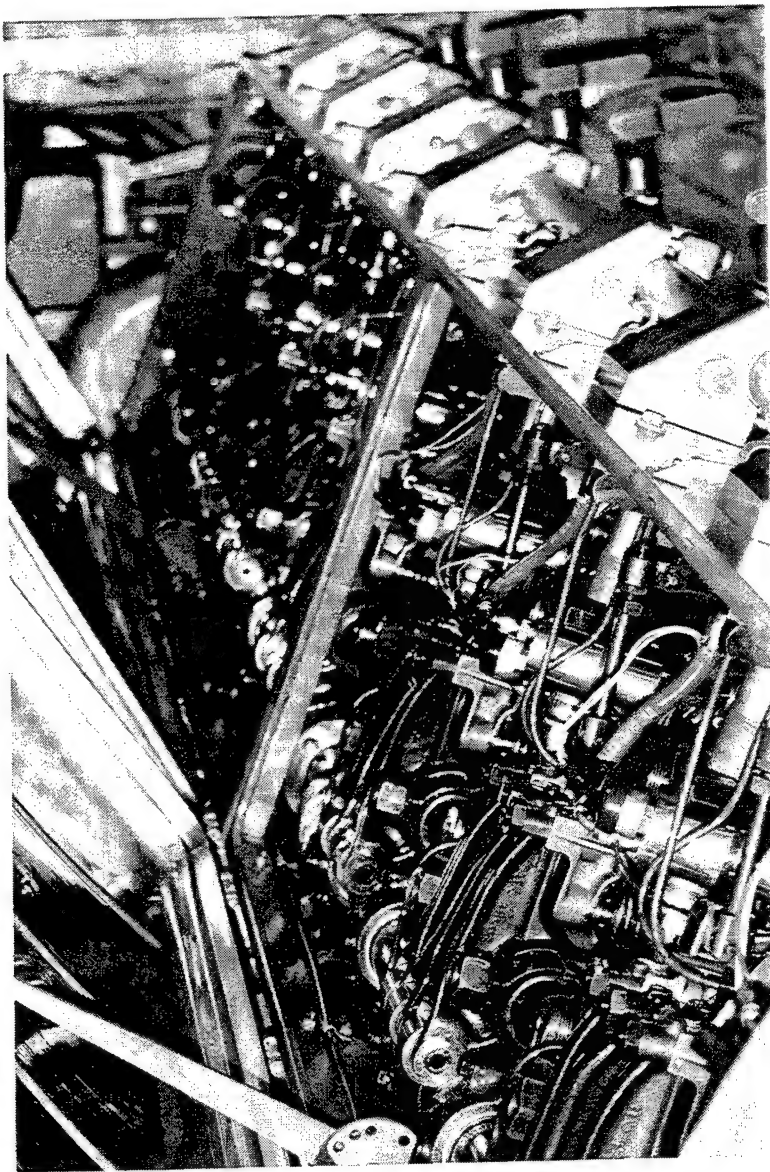
(b) Modified piston.

Figure 4-5. Engine modification components.





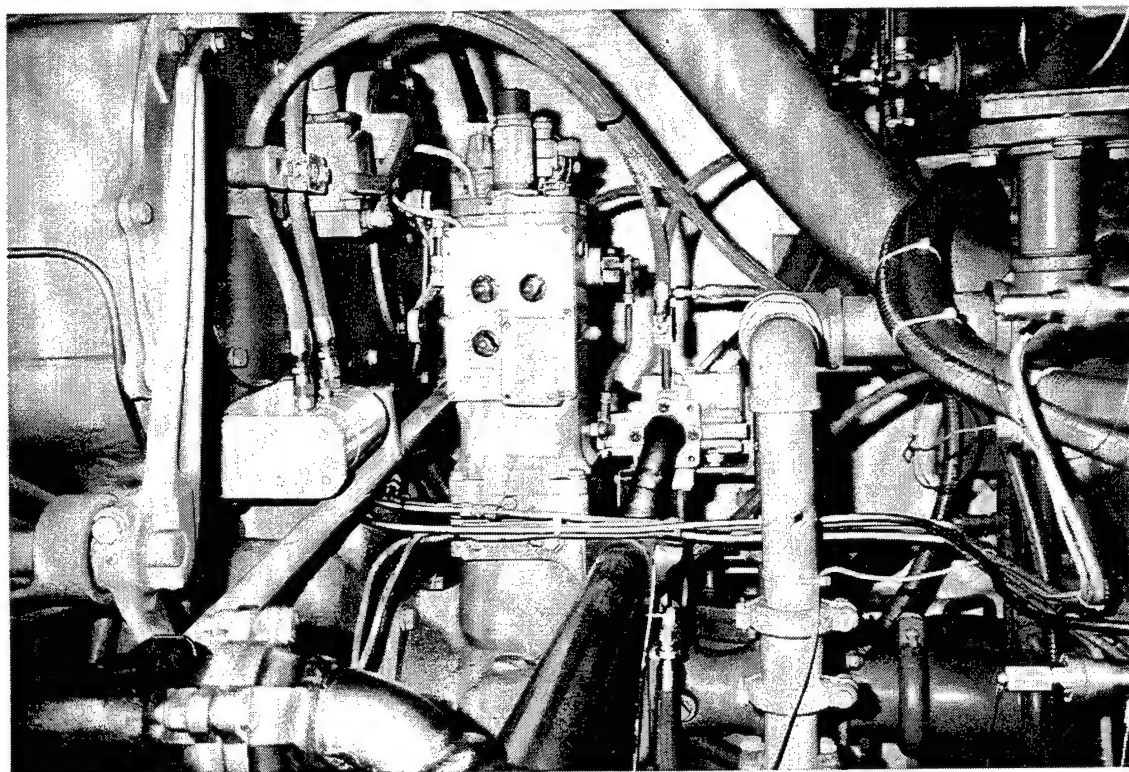
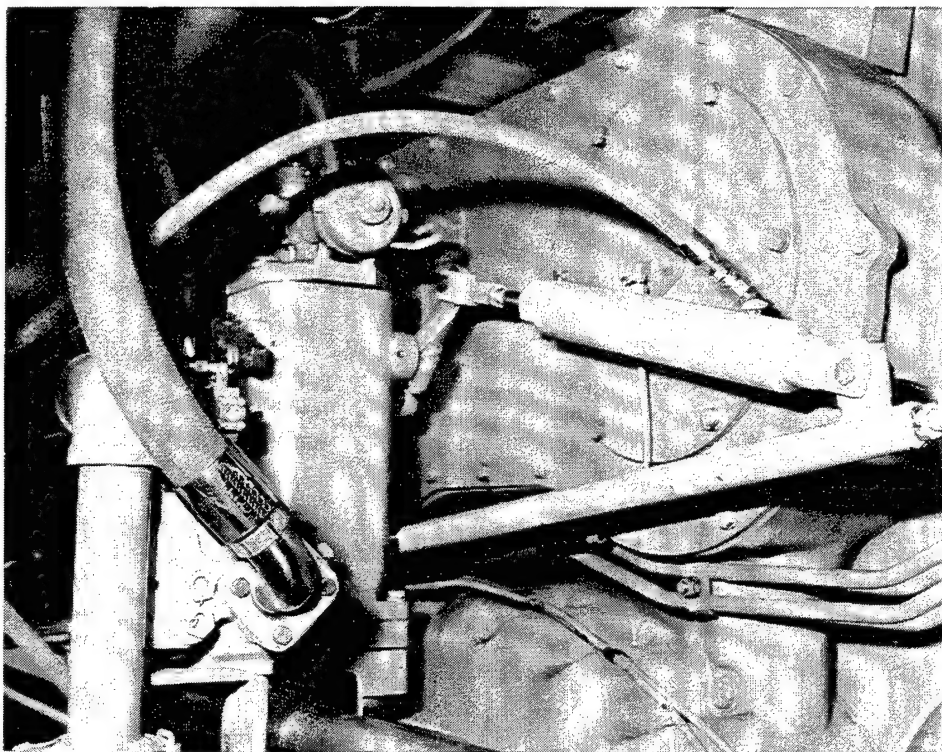
(c) Cylinder head with GIV.



(d) NG load blocks, GIV's, NG hoses, and actuating air hoses installed.

Figure 4-5. Engine modification components. (Cont'd.)

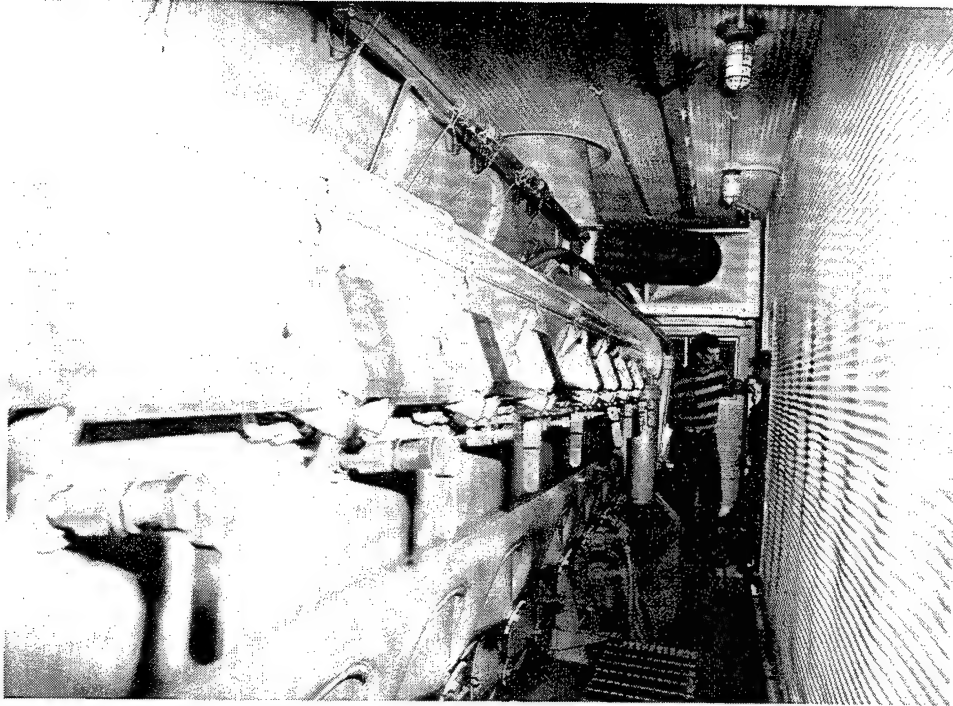
- (e) Air-actuated diesel ram control and NG supply hose leading to gas flow control valve (GFCV) mounted adjacent to governor.



- (f) Air-actuated pilot fuel stop assembly and governor output linkage to GFCV.

Figure 4-5. Engine modification components. (Cont'd.)



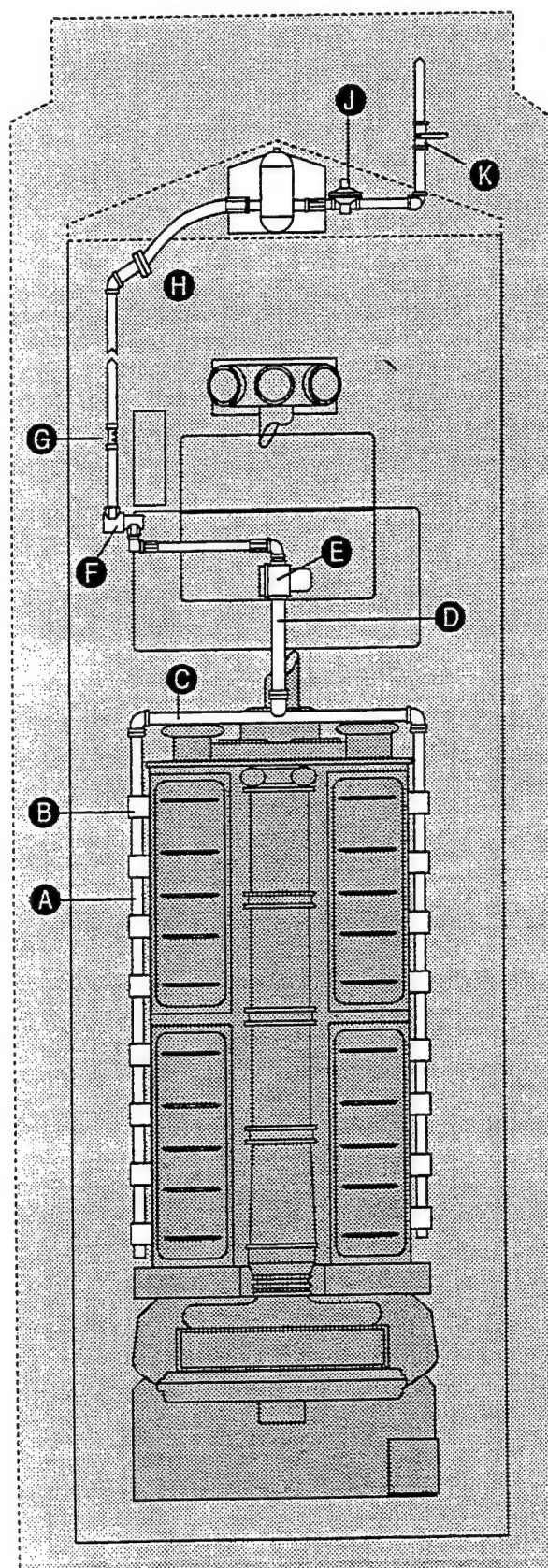


(g) NG header, load blocks, and cylinder relief valves installed.

Figure 4-5. Engine modification components. (Cont'd.)

Figure 4-6. Plan view of natural gas piping and components.

(Used by permission, Energy Conversions, Inc., U.S.A., 1996.)



- A. Gas header
  - B. Load blocks
  - C. Crossover header
  - D. Crossover hose
  - E. Gas flow control valve (GFCV)
  - F. Gas cutoff valve (GCOV)
  - G. Differential pressure sensor
  - H. Pipe-O-ring hose flange
  - J. Regulator
  - K. Manual shutoff valve
- } External to engine house (See Figs. 4-7 and 4-8).

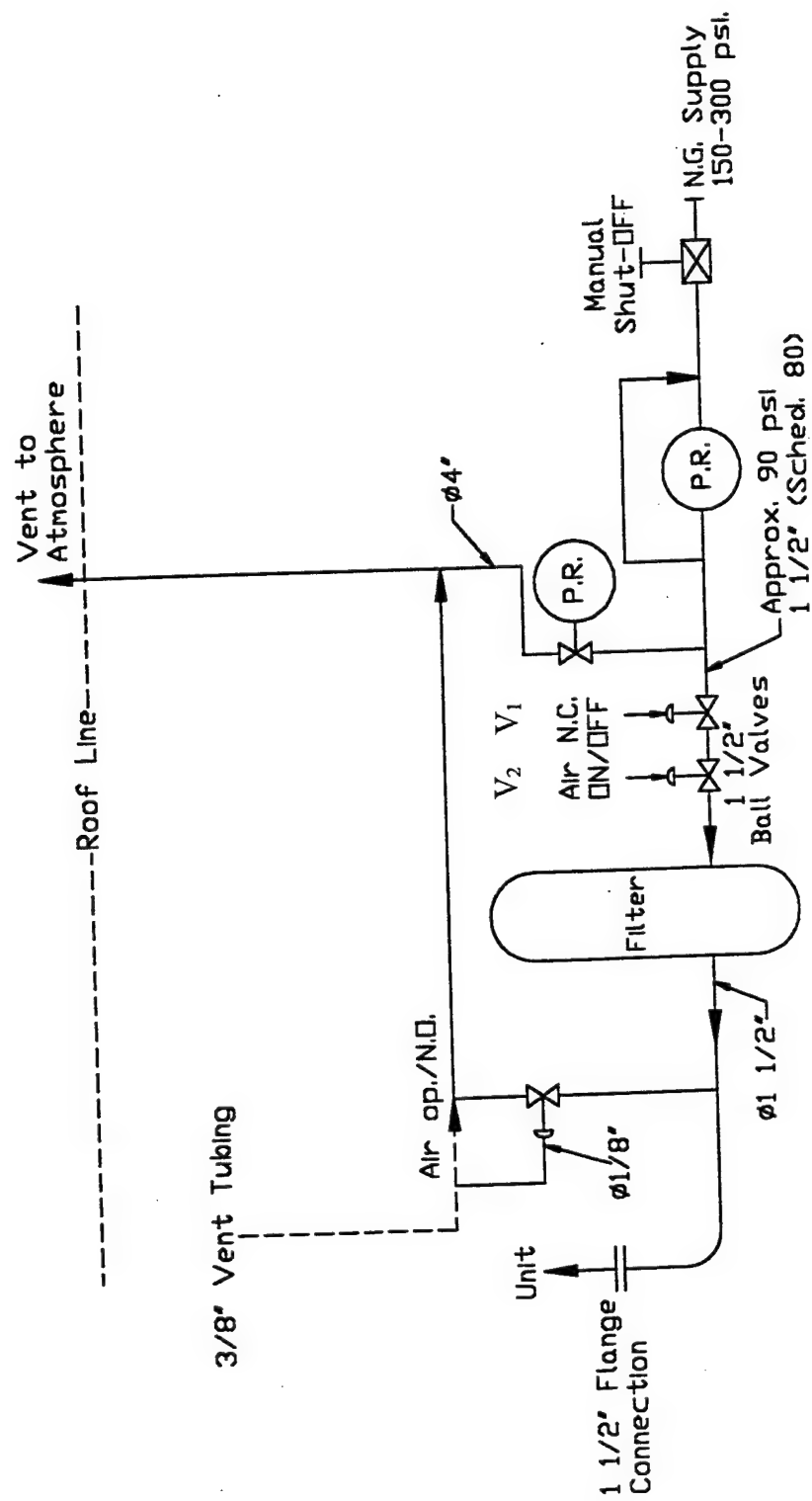
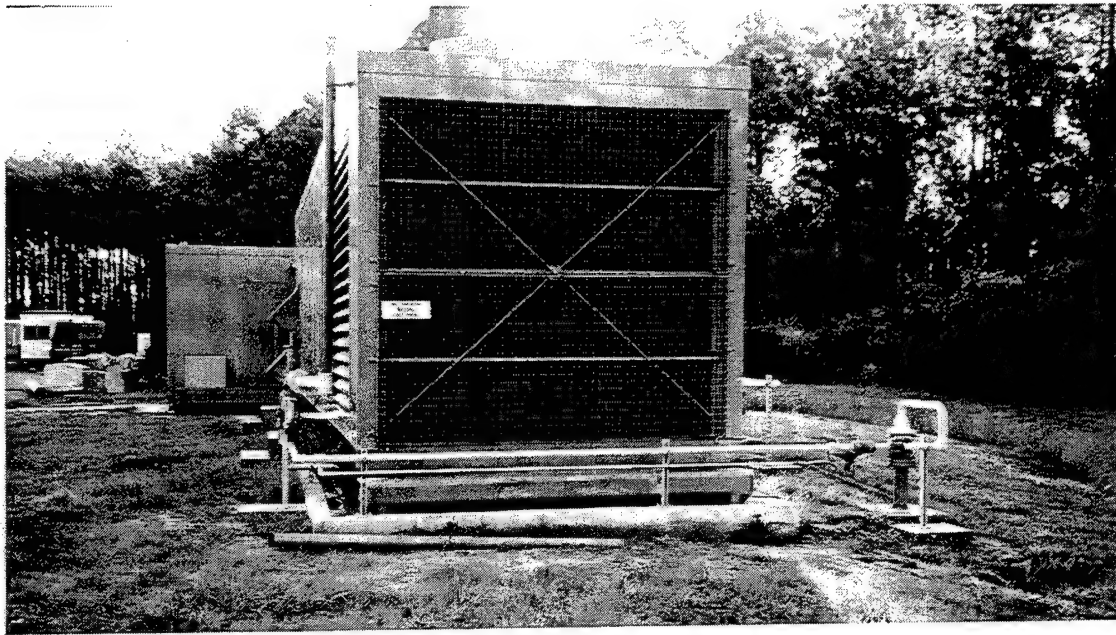
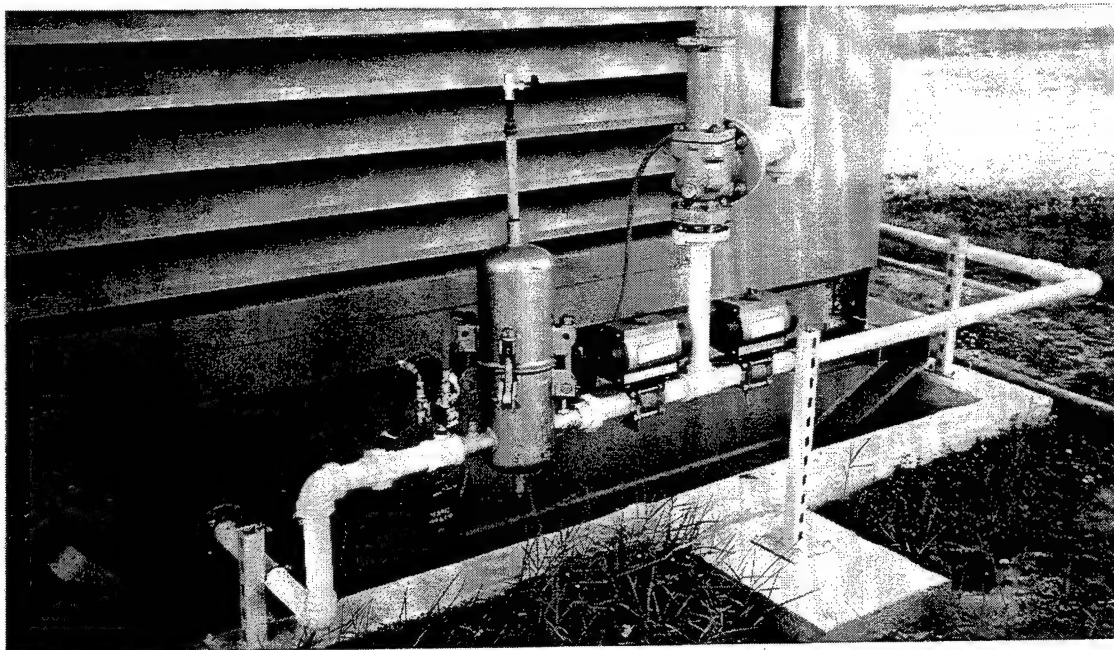


Figure 4-7. Natural gas piping components external to MUSE unit.



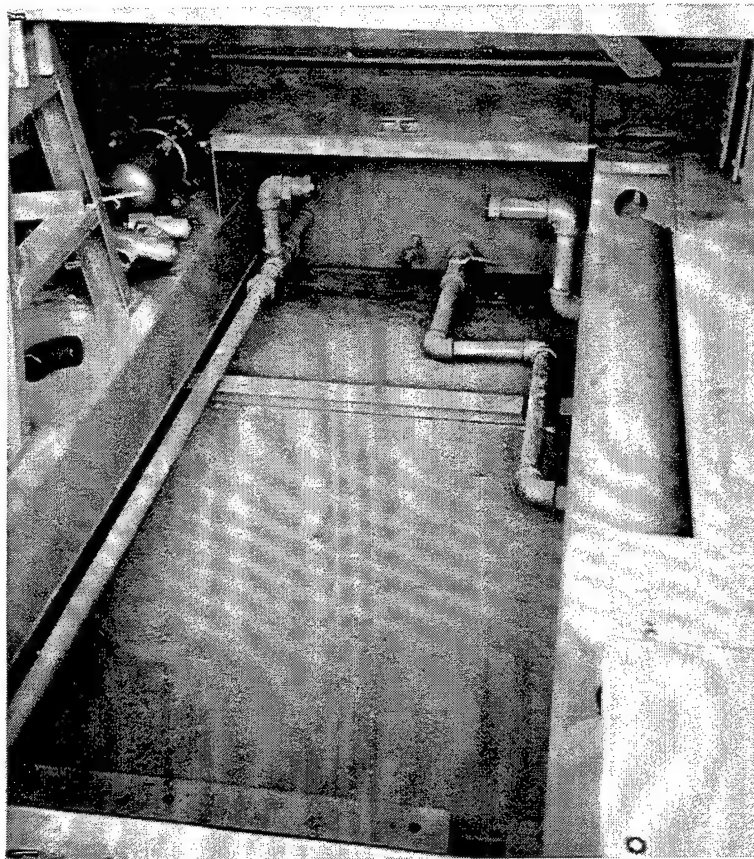
(a) From right, NG supply, manual shutoff valve, and pressure regulator with sensing line. Use schedule 80 steel piping for added mechanical safety.



(b) Two air-actuated ball valves, 150 psig relief valve with a 4-inch vent tube, filter, and air-actuated valve to vent NG line.

Figure 4-8. Natural gas (NG) supply line and components.

(c) Compressed air tank removed inside radiator room.

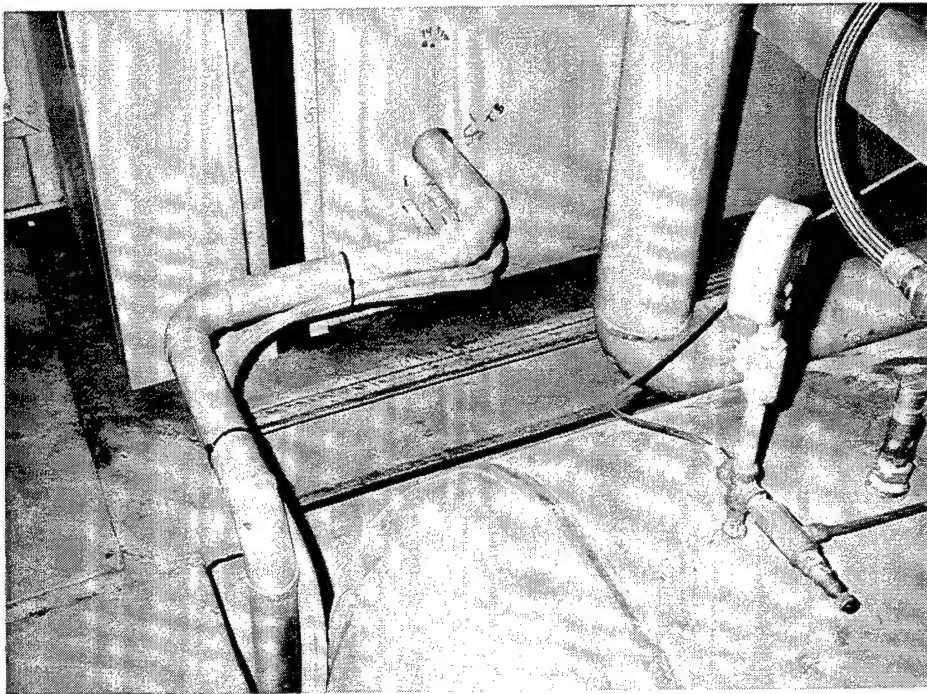


(d) NG line welded in place in radiator room.

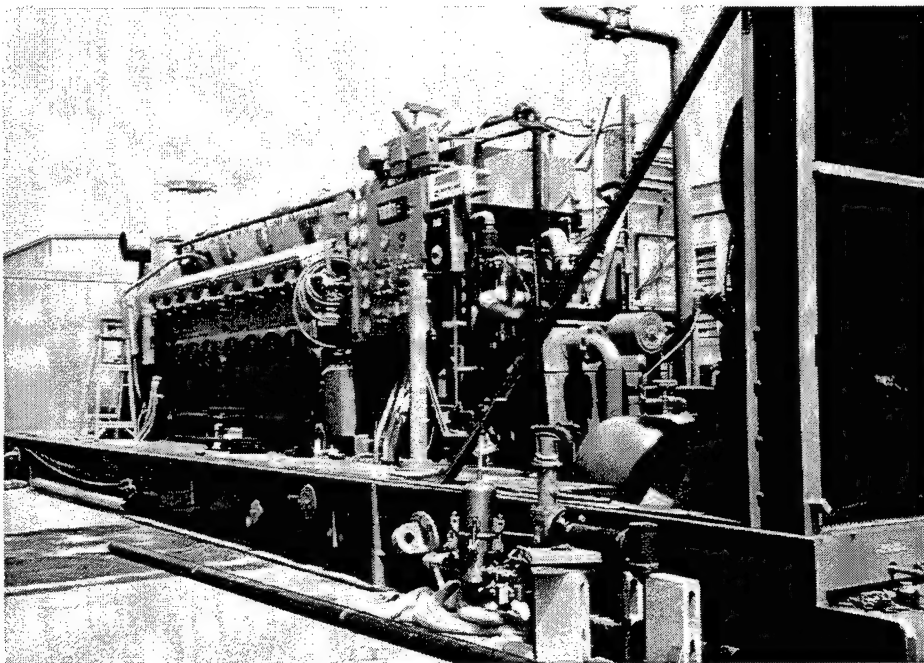


Figure 4-8. Natural gas (NG) supply line and components.(Cont'd.)



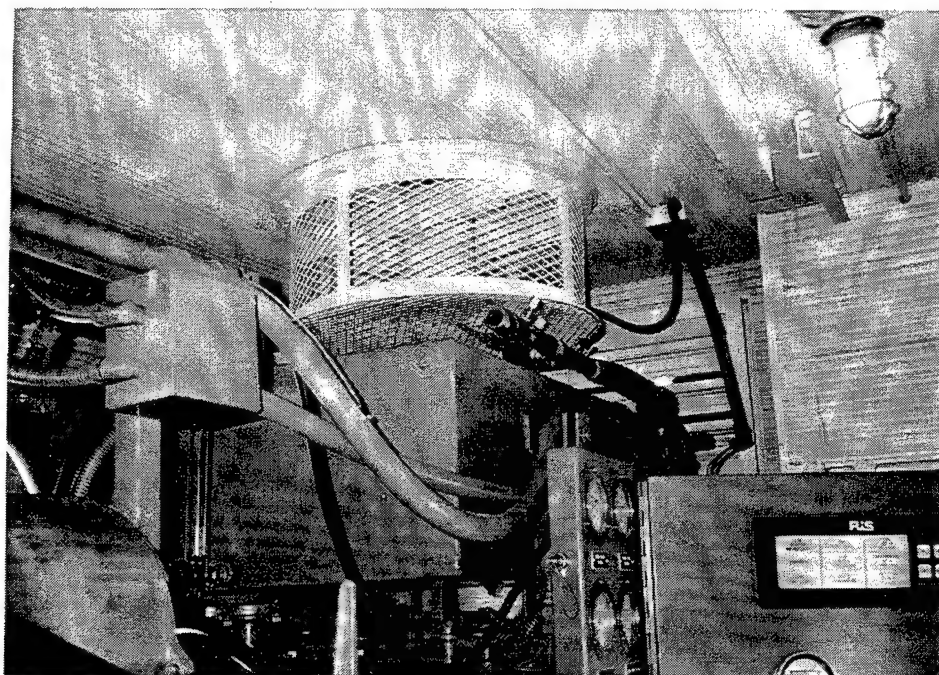


(e) NG piping passes through the radiator room, past compressed air tank and through wall into engine compartment. Actuating air lines from ASC are routed along with NG piping.

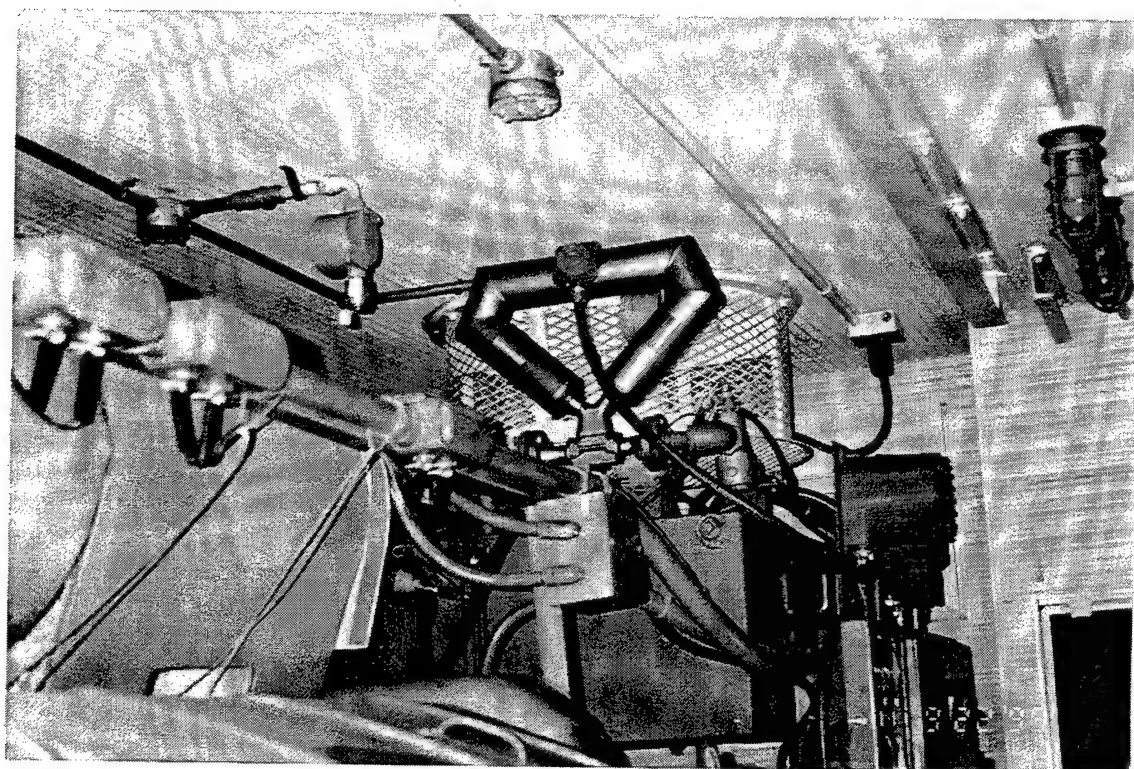


(f) NG line rises to top of engine compartment and enters metering run.

Figure 4-8. Natural gas (NG) supply line and components. (Cont'd.)



(g) Metering run is initiated (see Fig. 4-9) --

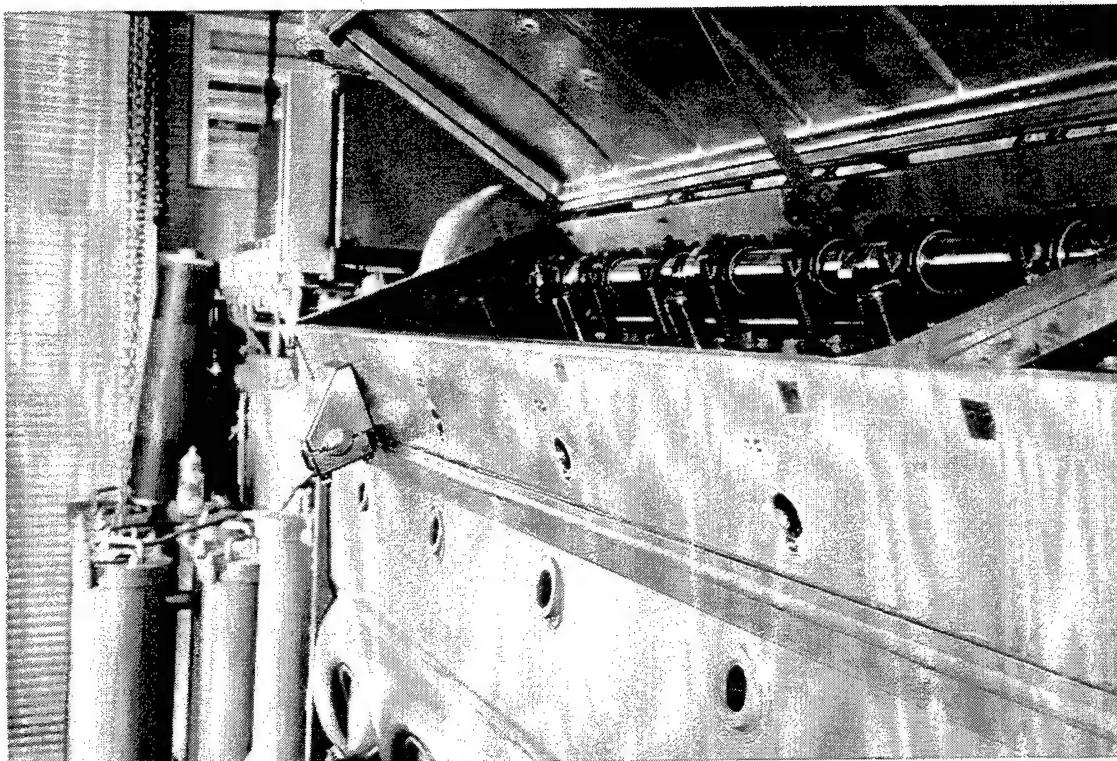


(h) and completed. Mass flow meter is added for test purposes in addition to standard differential pressure measurement.

Figure 4-8. Natural gas (NG) supply line and components. (Cont'd.)



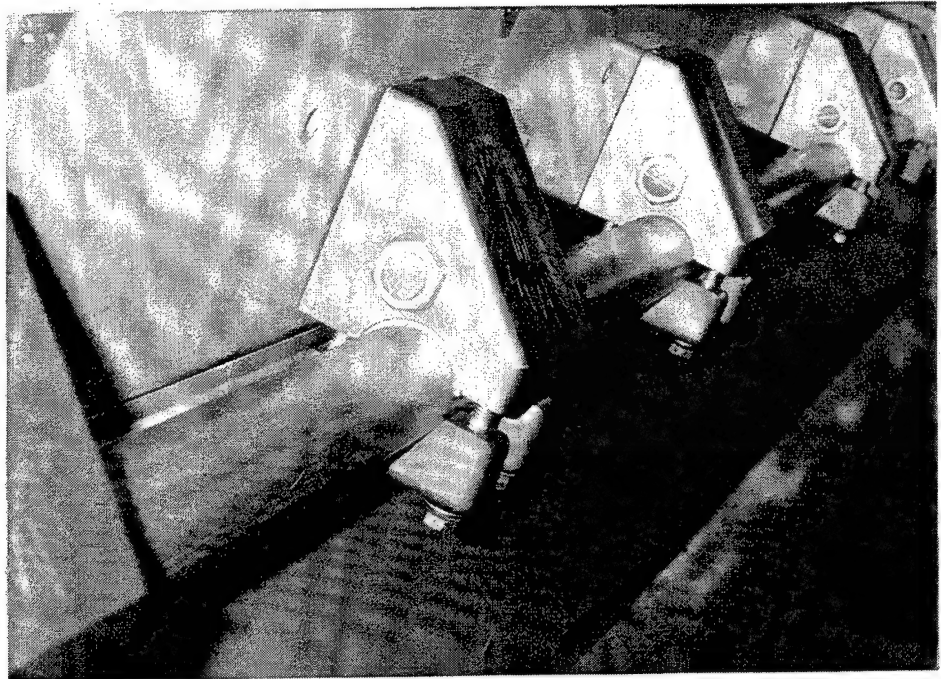
(i) Installing an NG load block.



(j) One NG load block installed, mounting holes cut.

Figure 4-8. Natural gas (NG) supply line and components. (Cont'd.)

(k) Load blocks and NG header installed.



(l) NG supply line with gas and air hoses to cylinders installed.

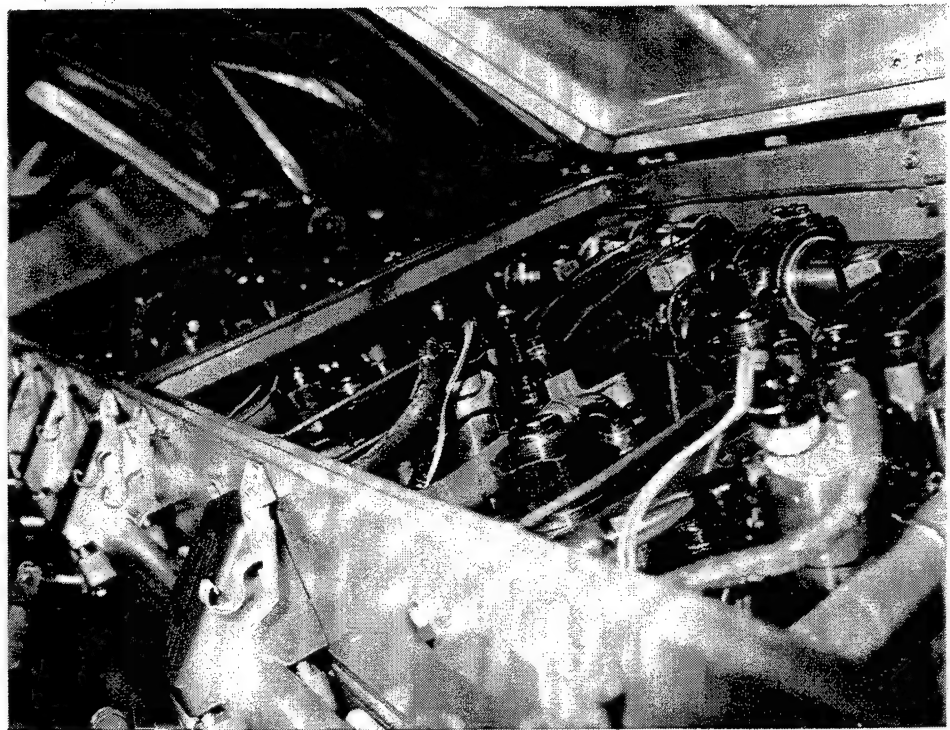
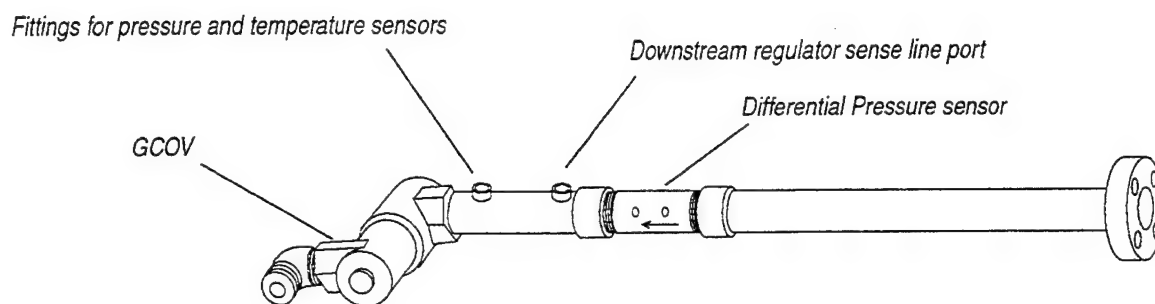
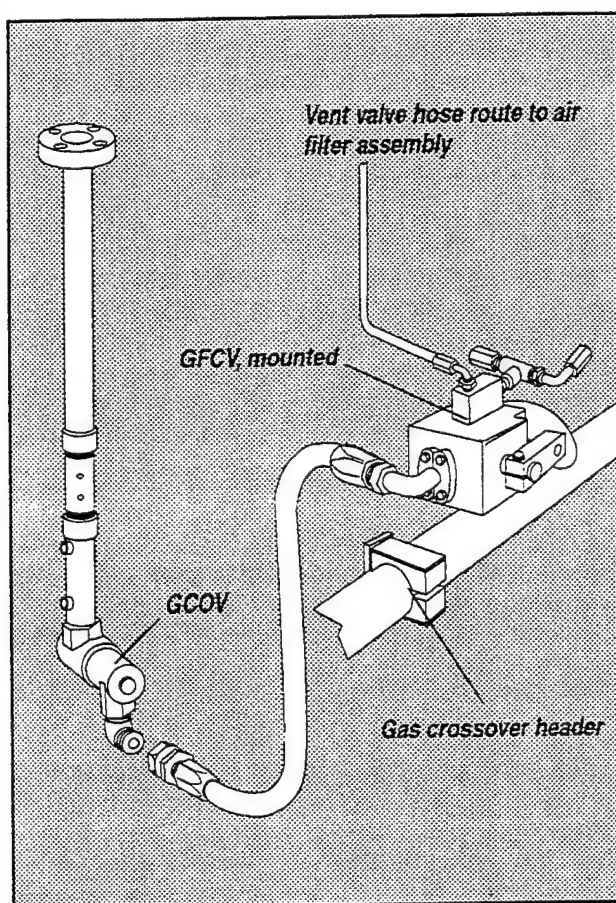


Figure 4-8. Natural gas (NG) supply line and components. (Cont'd.)



**Figure 4-9. ECI-supplied NG metering assembly.**  
*(Used by permission, Energy Conversions, Inc., U.S.A., 1996.)*



**Figure 4-10. Attaching gas line to GFCV.**  
*(Used by permission, Energy Conversions, Inc., U.S.A., 1996.)*

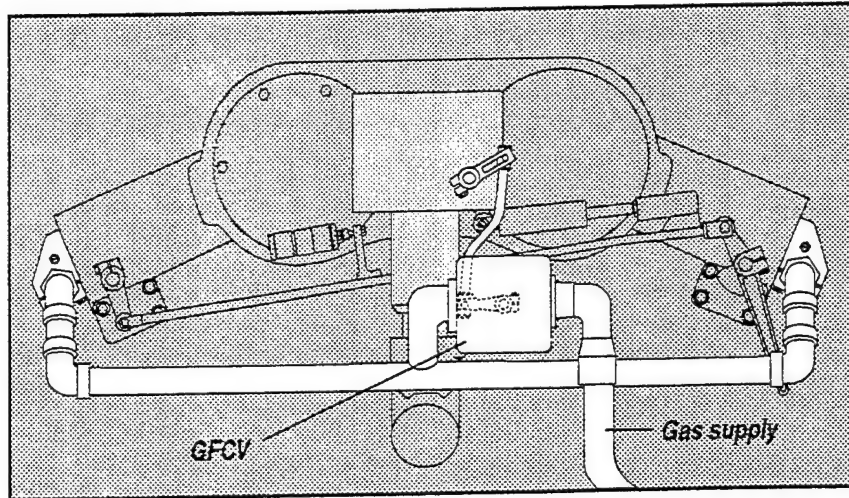


Figure 4-11. The GFCV is mounted adjacent to governor.  
(Used by permission, Energy Conversions, Inc., U.S.A., 1996.)

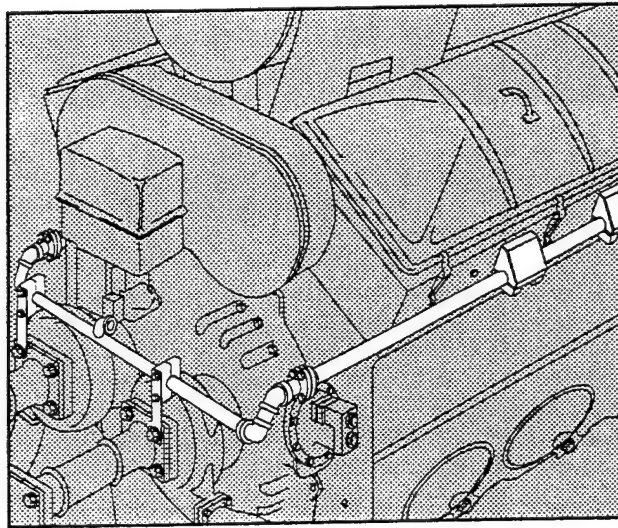


Figure 4-12. Gas header to cylinders.  
(Used by permission, Energy Conversions, Inc., U.S.A., 1996.)

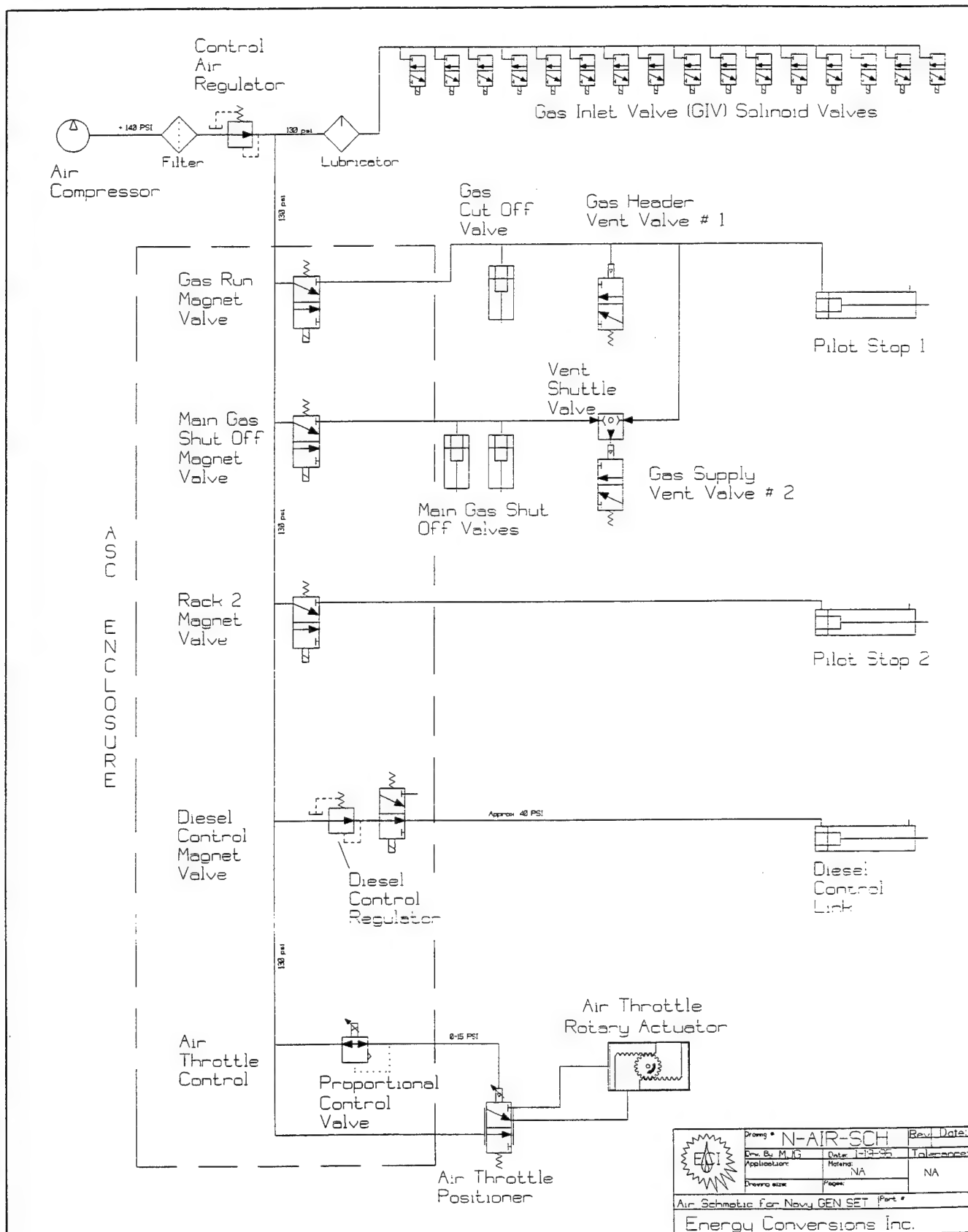


Figure 4-13. Compressed air supply ASC and usage schematic.

(Used by permission, Energy Conversions, Inc., U.S.A., 1996.)



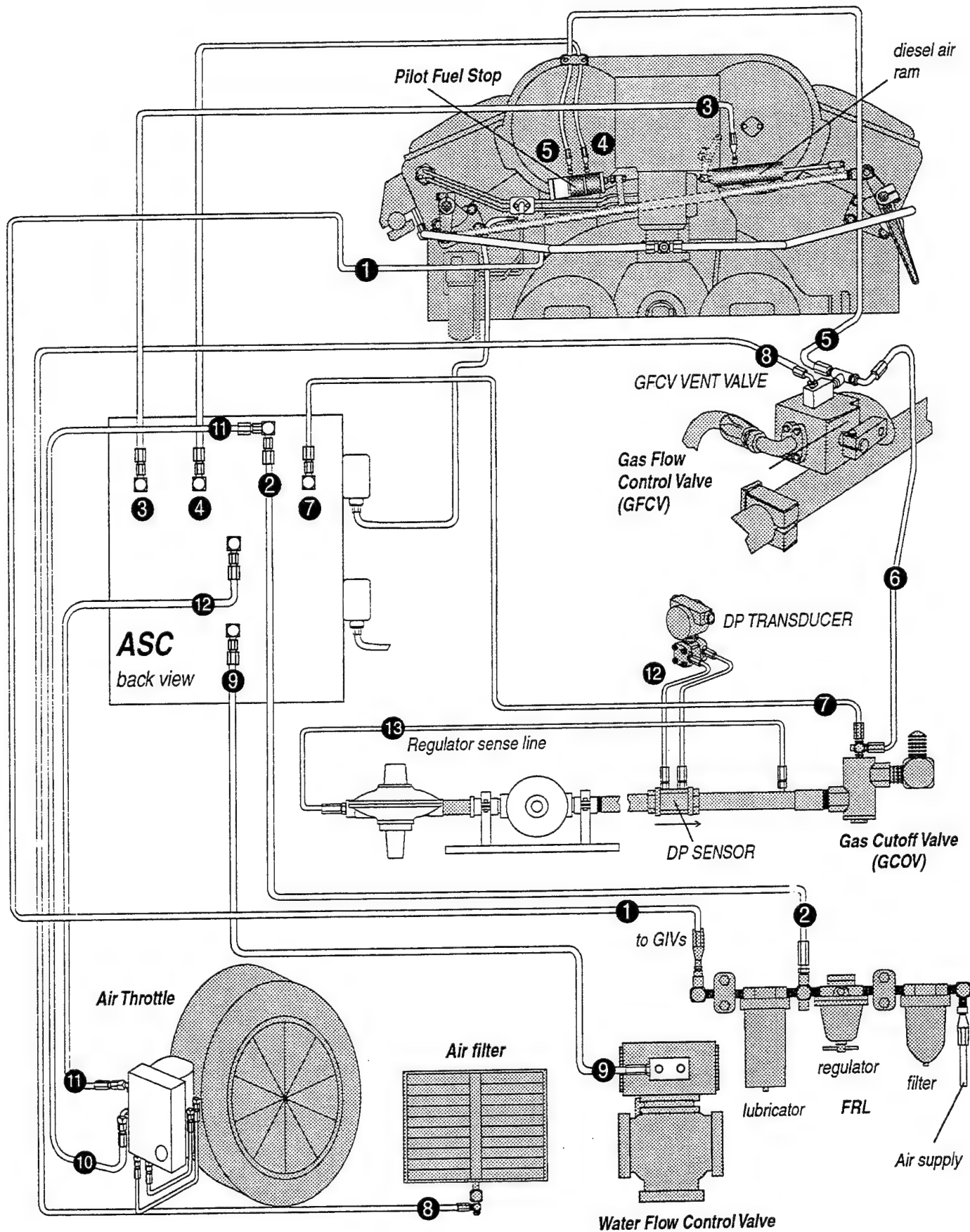
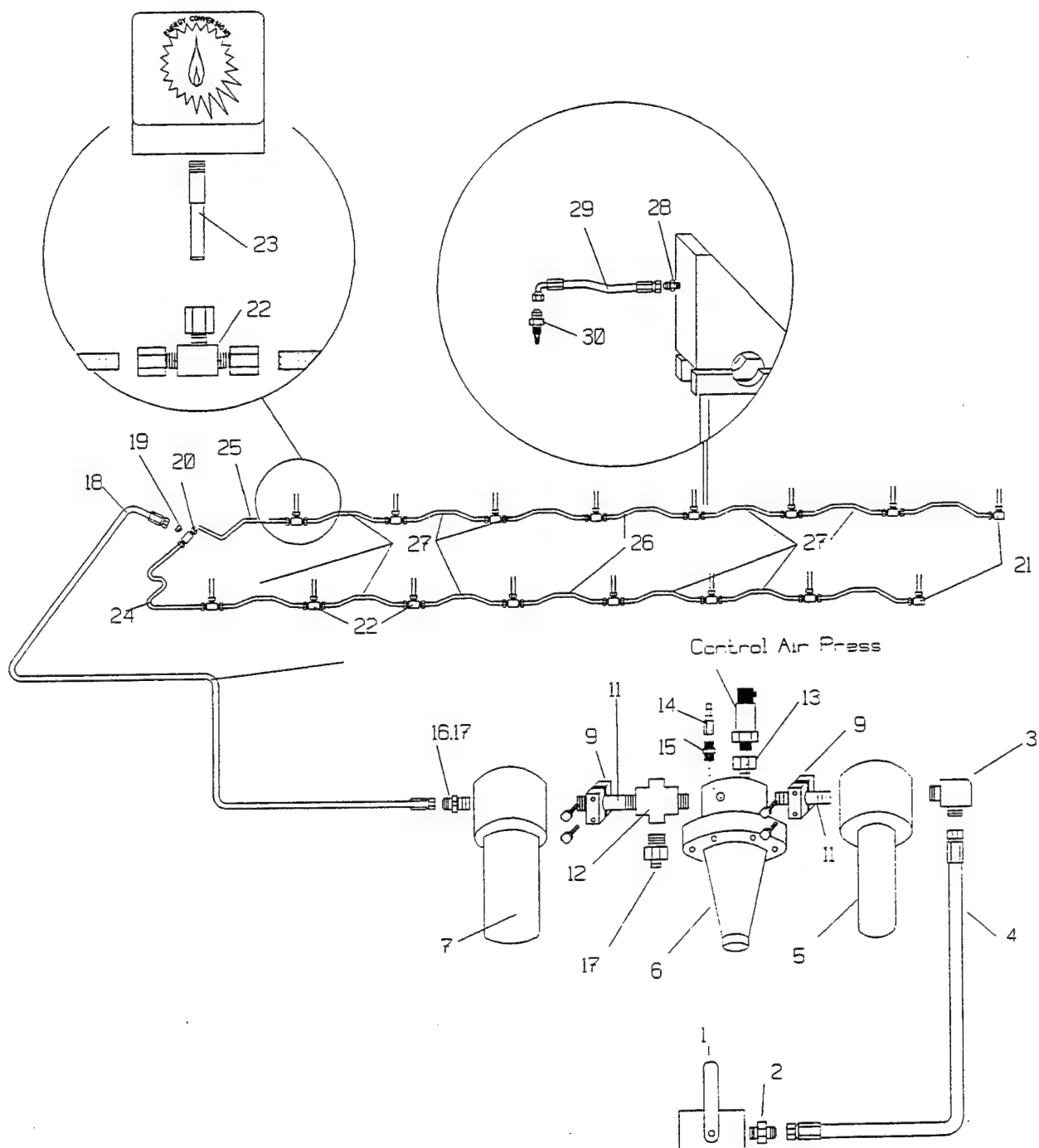


Figure 4-14. Pictorial of air hose connections.  
(Used by permission, Energy Conversions, Inc., U.S.A., 1996.)



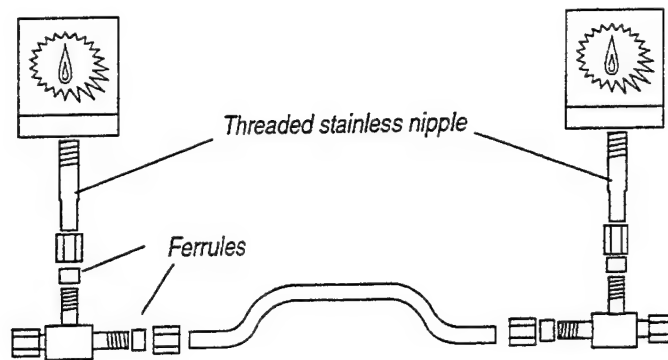
Note: Air Piping Hardware:

Ref. No.	Description	Ref. No.	Description	Ref. No.	Description
1	Air shutoff valve	13	Bushing	23	Fitting: SS custom nipple
2	Fitting valve to hose	14	Fitting test point	24	Tube engine - front left
3	Fitting oiler inlet	15	Fitting nipple	25	Tube engine - front right
4	Hose assembly	16	Fitting oiler outlet	26	Tube engine - center jumper
5	Filter	17	Fitting adapter	27	Tube engine jumpers
6	Regulator	18	Hose assy.	28	Fitting
7	Oil	19	Fitting	29	Hose assembly
9	Mount bracket assy.	20	Fitting: male branch tee	30	Fitting - GIV AIR w/filter
11	Fitting: connector	21	Fitting: union elbow		
12	Fitting tee	22	Fitting: union tee		

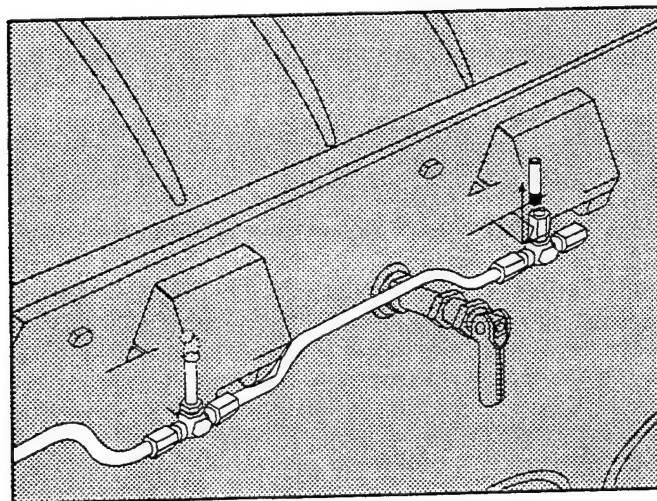
Figure 4-15. Schematic diagram of air tubing to GIV's.

(Used by permission, Energy Conversions, Inc., U.S.A., 1996.)



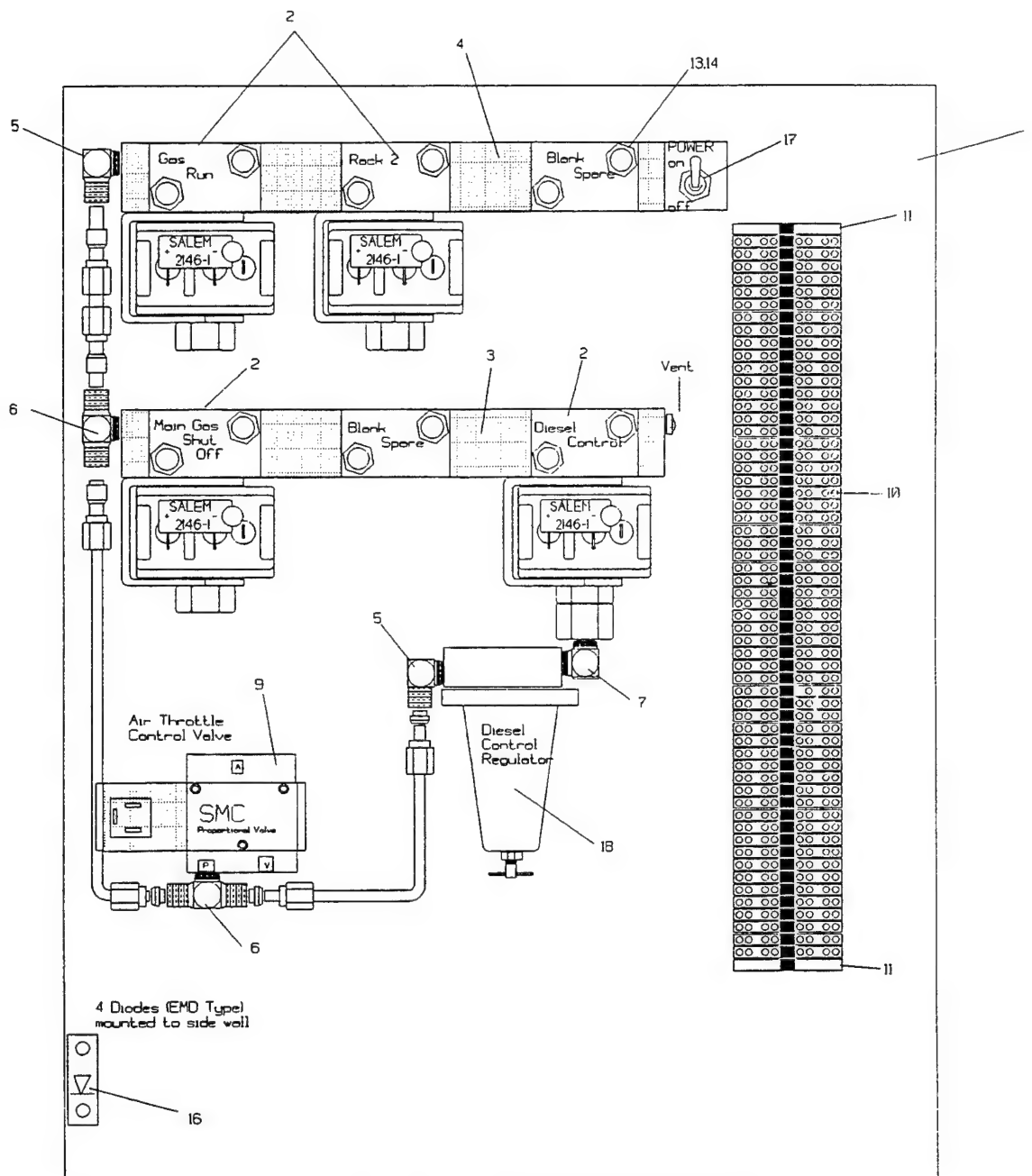


(a) Connection to load blocks.



(b) Route around cylinder relief valves.

Figure 4-16. Routing of GIV tubing for compressed air.  
*(Used by permission, Energy Conversions, Inc., U.S.A., 1996.)*



**Note:** Air Service Cabinet.

Ref. No.	Description	Ref. No.	Description	Ref. No.	Description
1	ASC assembly	6	Mounting block	13	Nut
2	Magnet valve	7	Fitting	14	Lockwasher
3	Mounting block	9	Press. control valve	16	Diode
4	Mounting block	10	Terminal block	17	Toggle switch
5	Fitting	11	Support	18	Pressure Regulator

**Figure 4-17. Internal Arrangement of ASC.**

*(Used by permission, Energy Conversions, Inc., U.S.A., 1996.)*

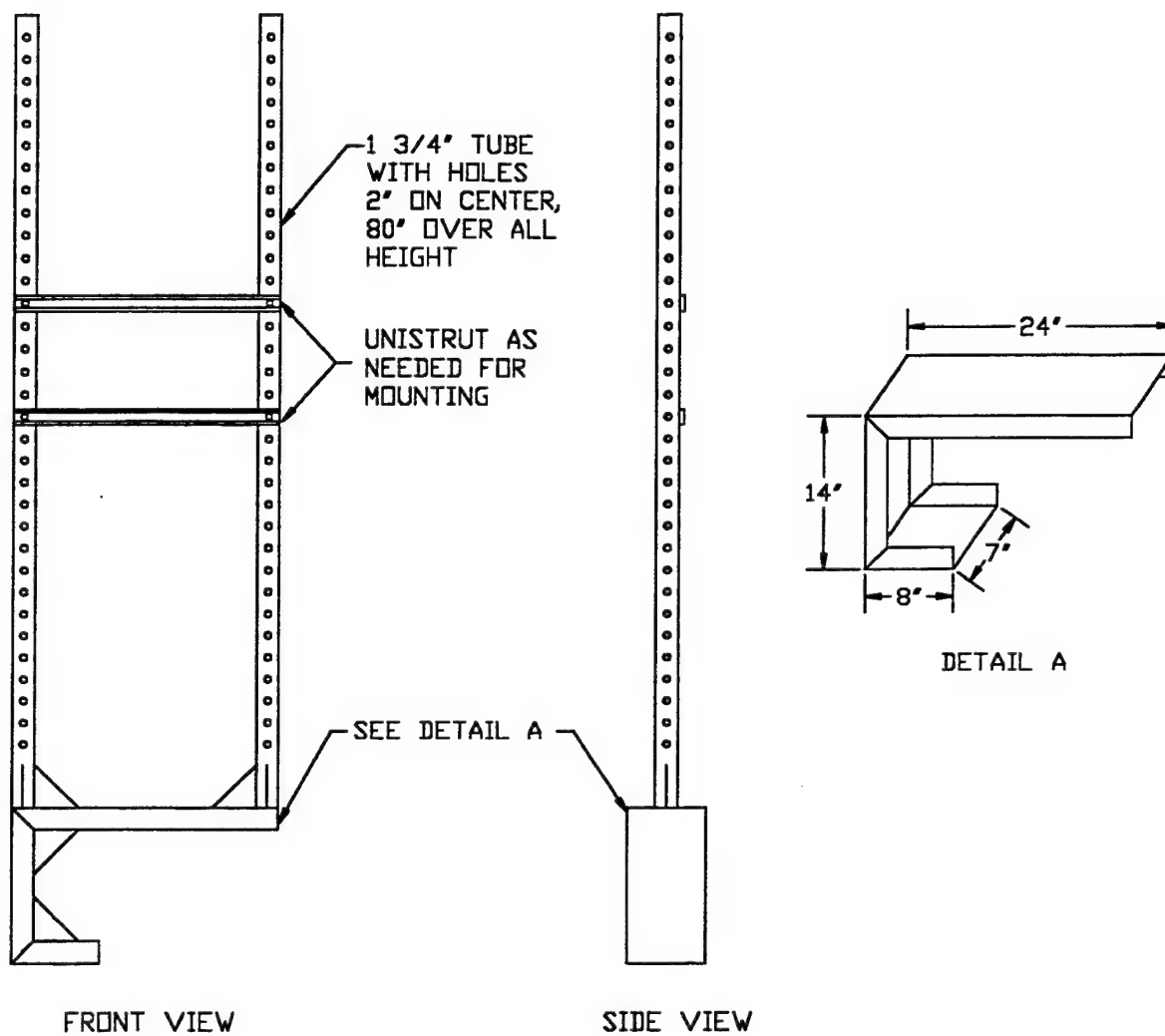
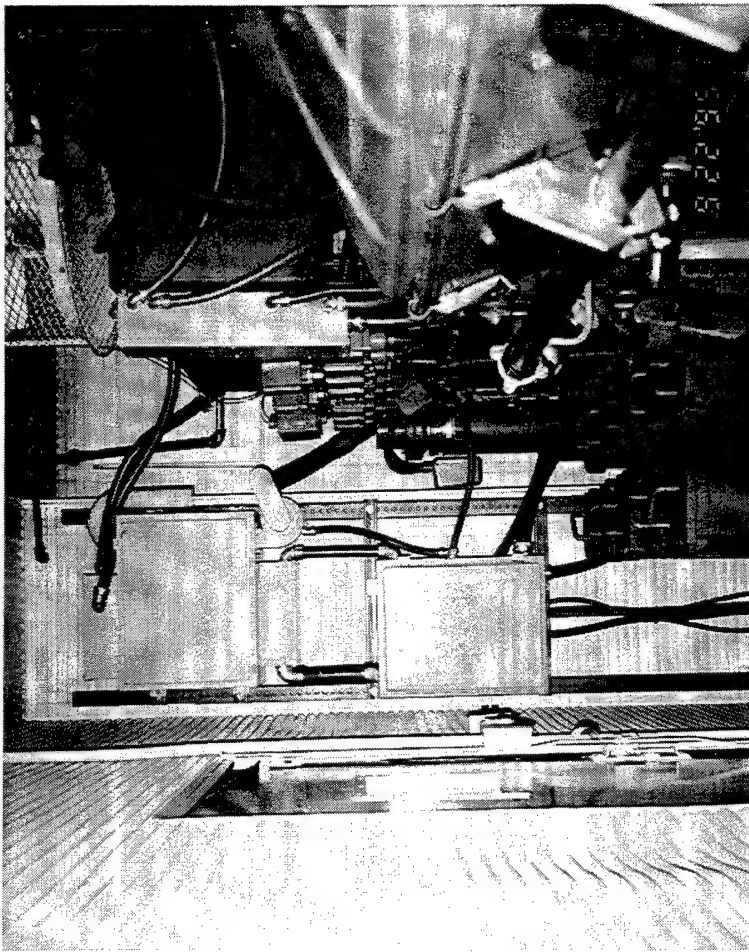
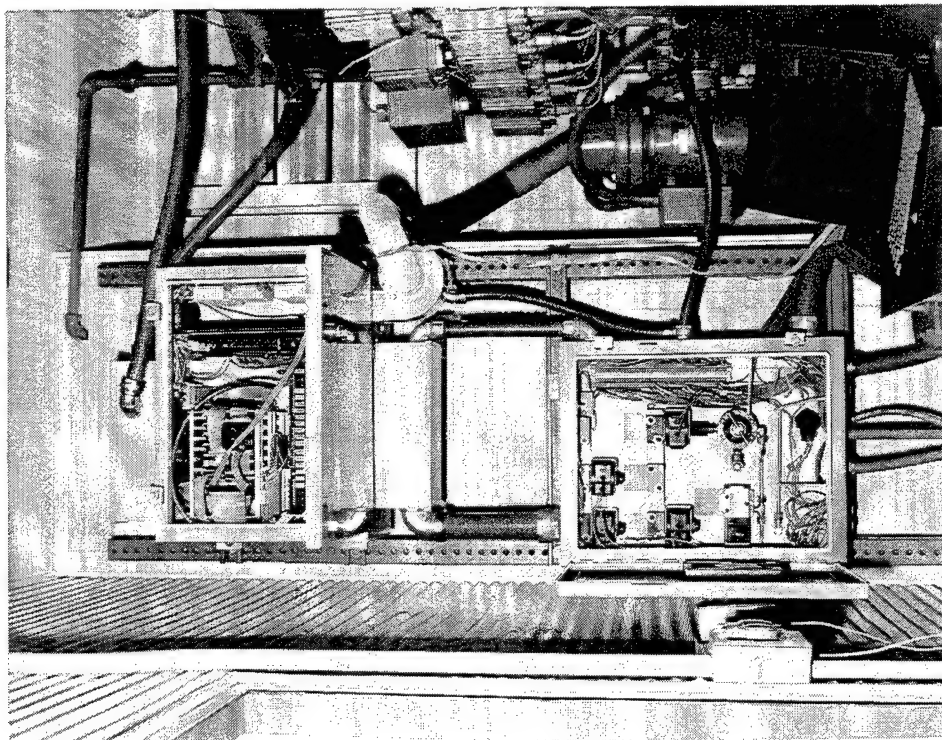


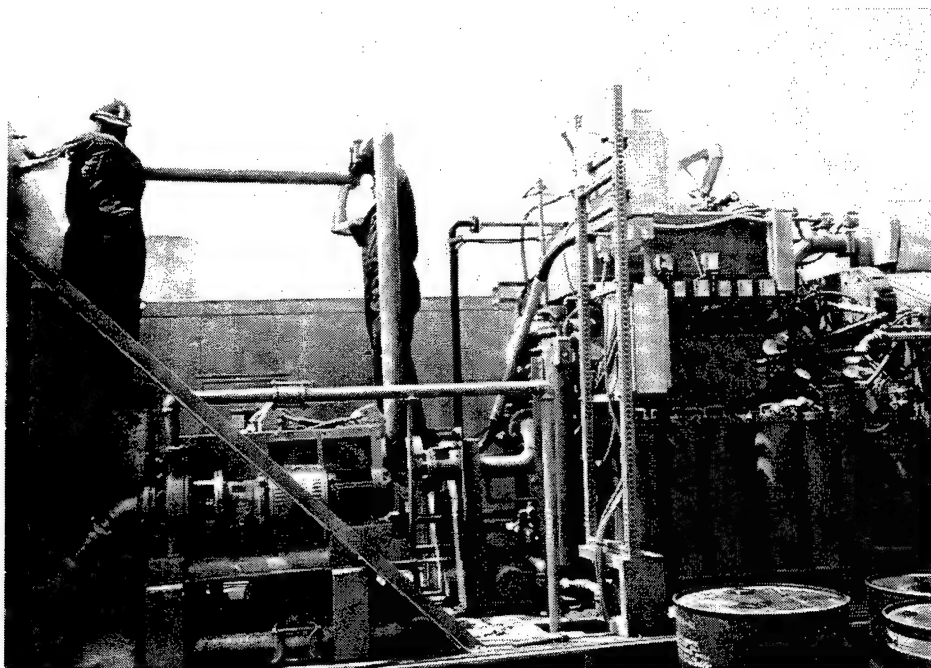
Figure 4-18. Mounting bracket for engine control unit (ECU) and air service cabinet (ASC).

(a) In process of checkout.



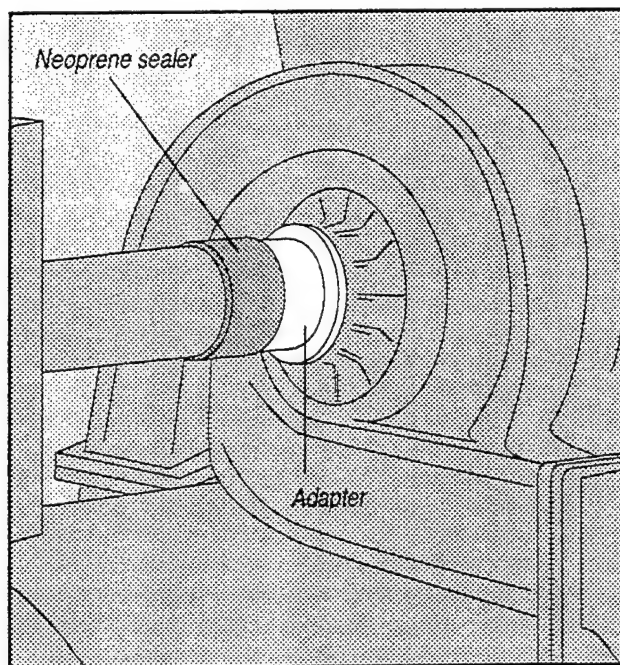
(b) Completed installation.

Figure 4-19. ECU and ASC mounted in engine house.

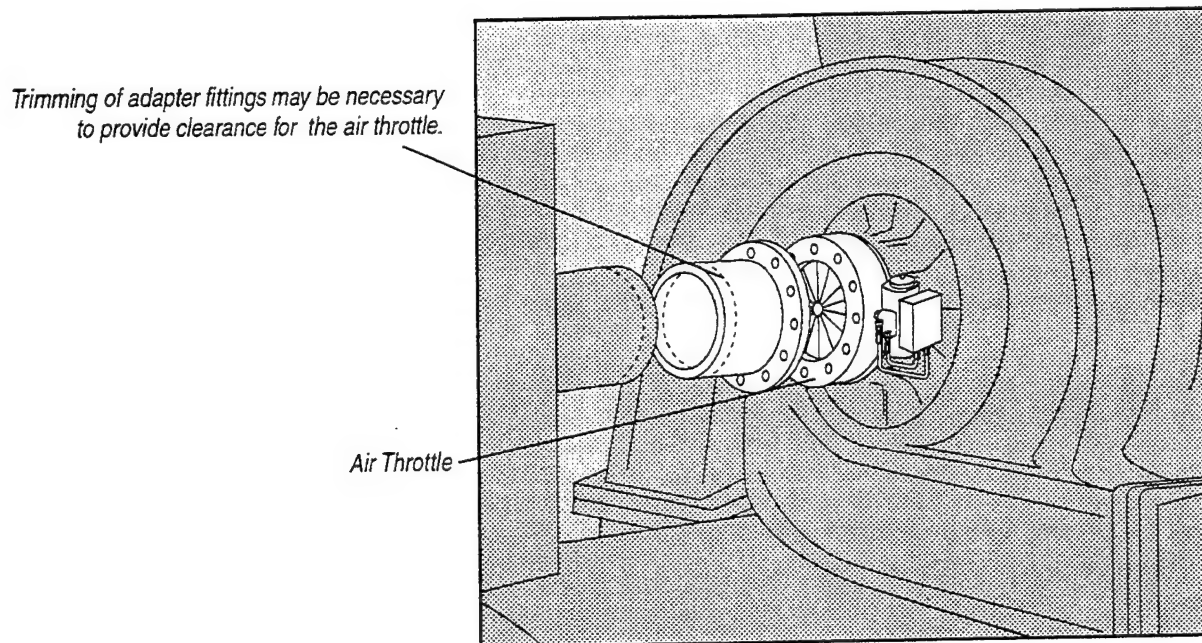


(c) Mounted on freestanding support bracket to allow engine generator set housing cover to be removed.

Figure 4-19. ECU and ASC mounted in engine house. (Cont'd.)



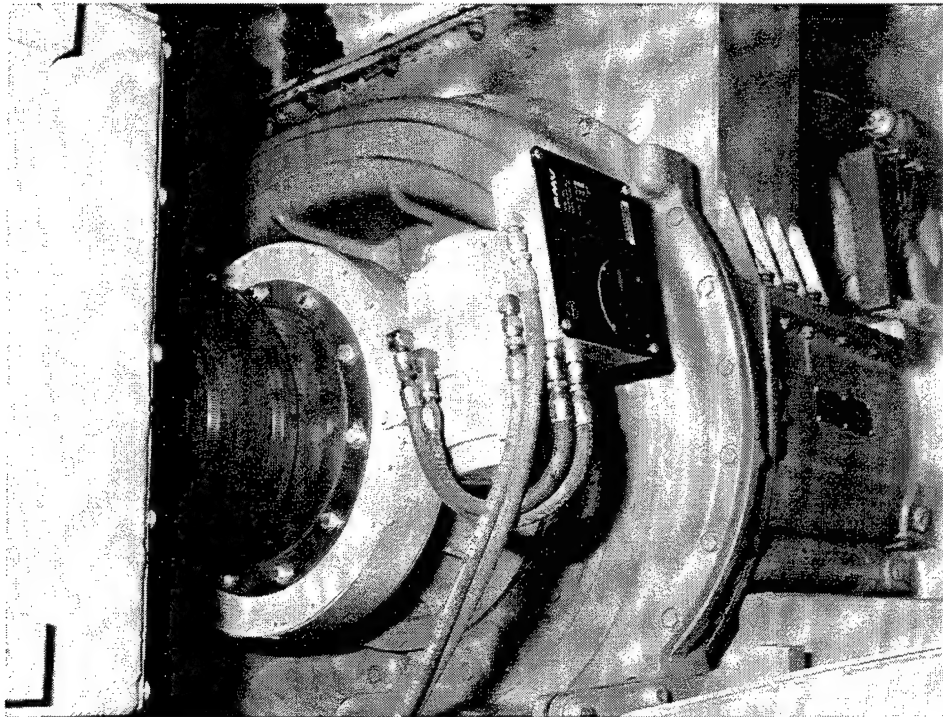
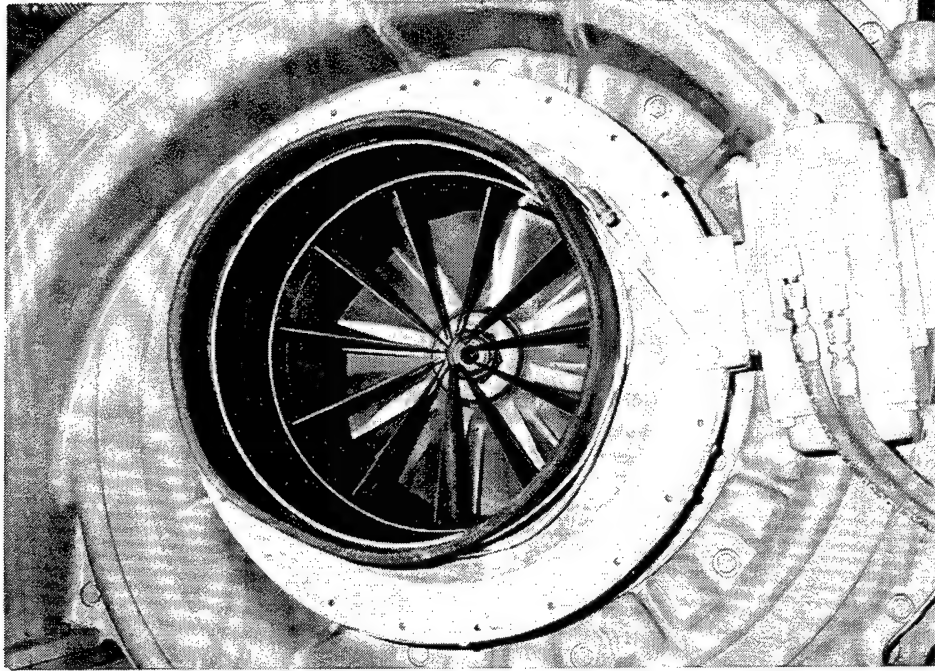
(a) Standard turbocharger with adapter fitting highlighted.



(b) Air throttle being installed with adapter fitting.

Figure 4-20. Turbocharger installation.  
(Used by permission, Energy Conversions, Inc., U.S.A., 1996.)





(b) Installation complete with air-actuated positioner.

Figure 4-21. Photographs of air throttle installation.



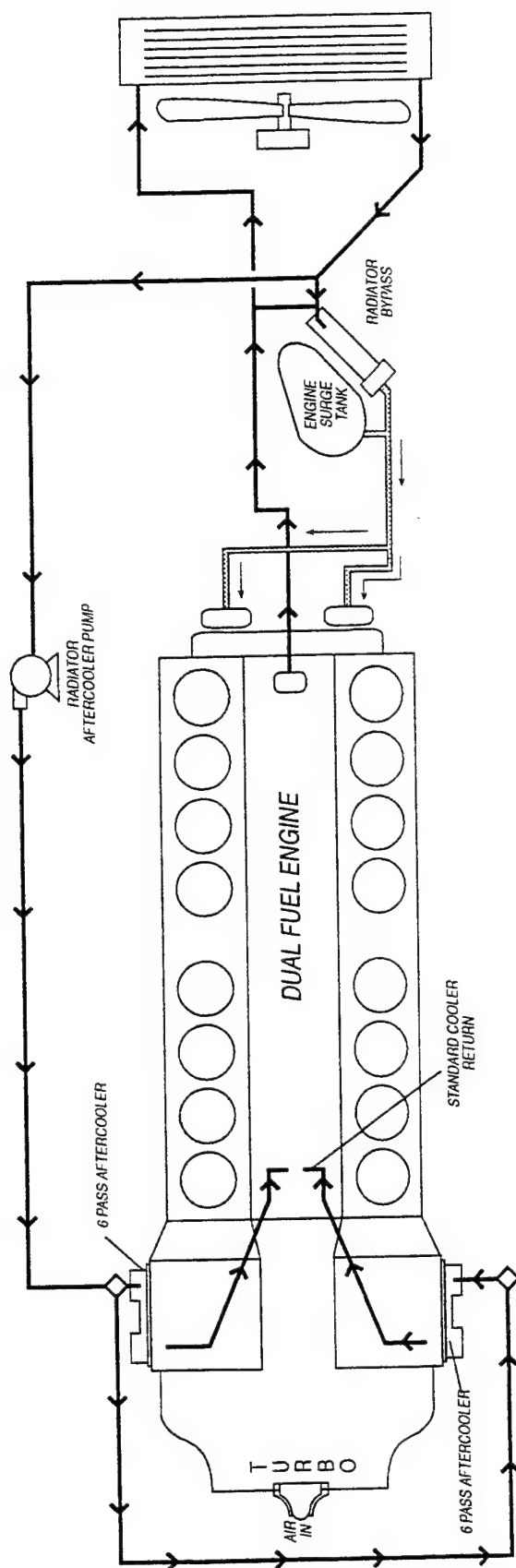
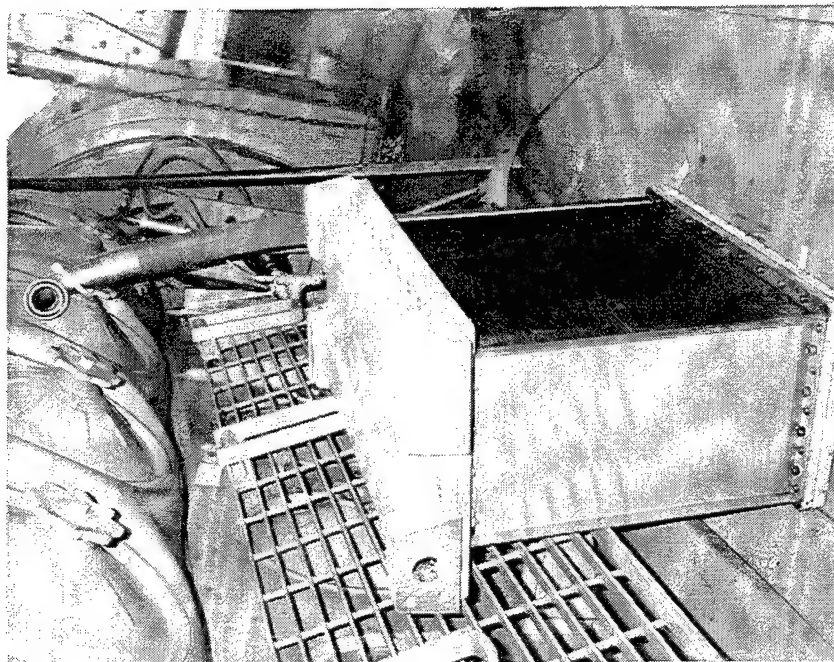
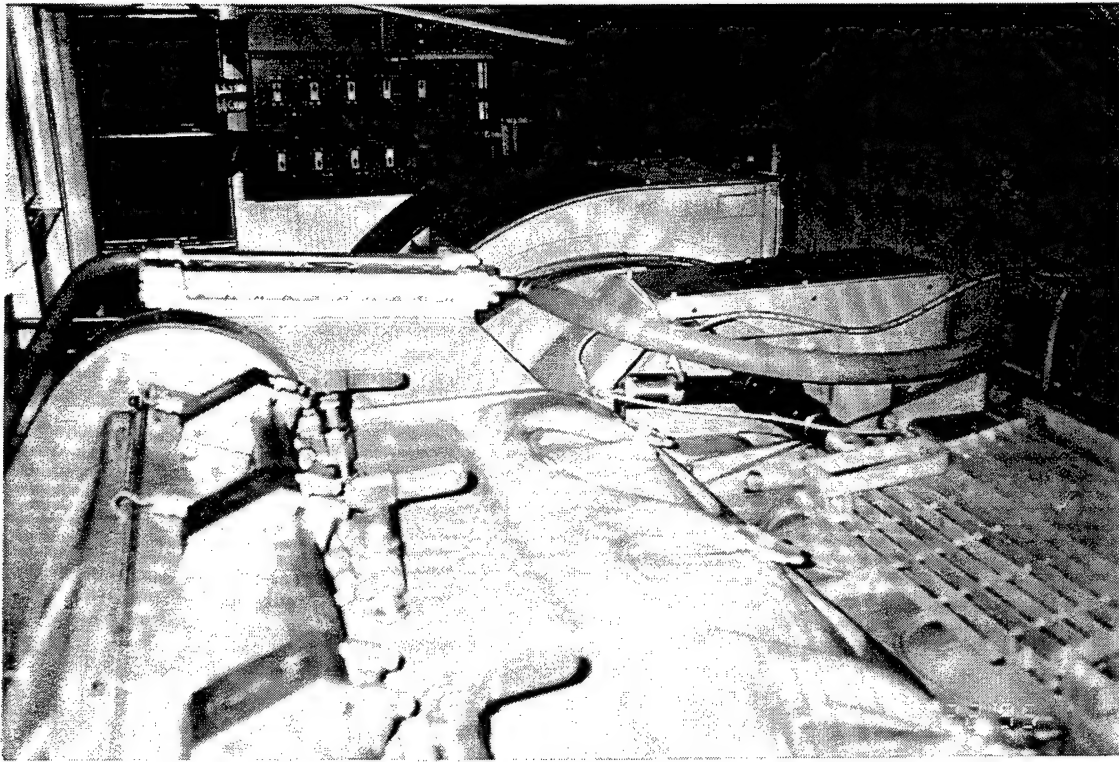


Figure 4-22. Schematic diagram of enhanced cooling system.  
(Used by permission, Energy Conversions, Inc., U.S.A., 1996.)



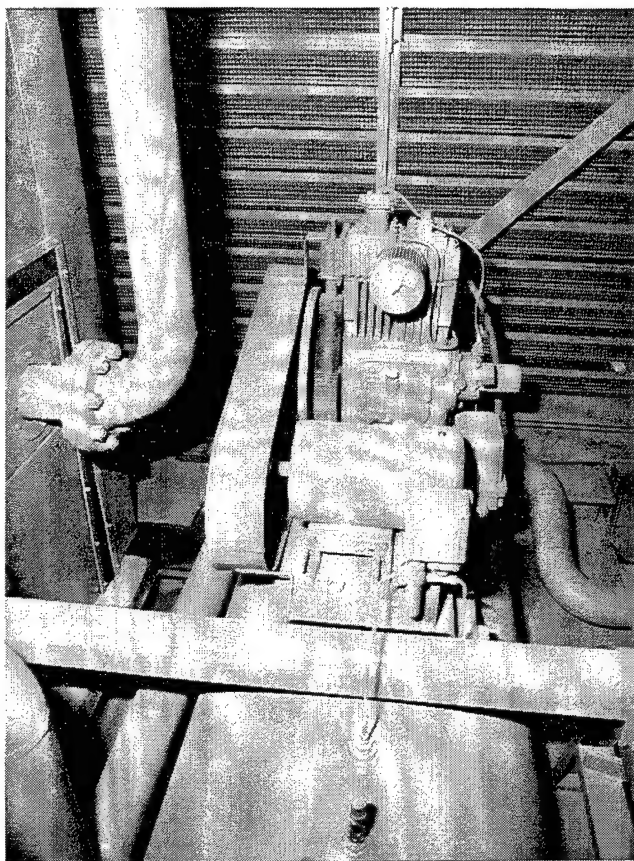
(a) 6-Pass aftercooler ready for installation.



(b) New aftercooler installed with modified water lines.

Figure 4-23. Aftercooler installation.

- (a) Original air compressor mounted longitudinally on air tank (interior view).



- (b) New air compressor (rear) and water pump with suction and outlet water lines installed (exterior view).

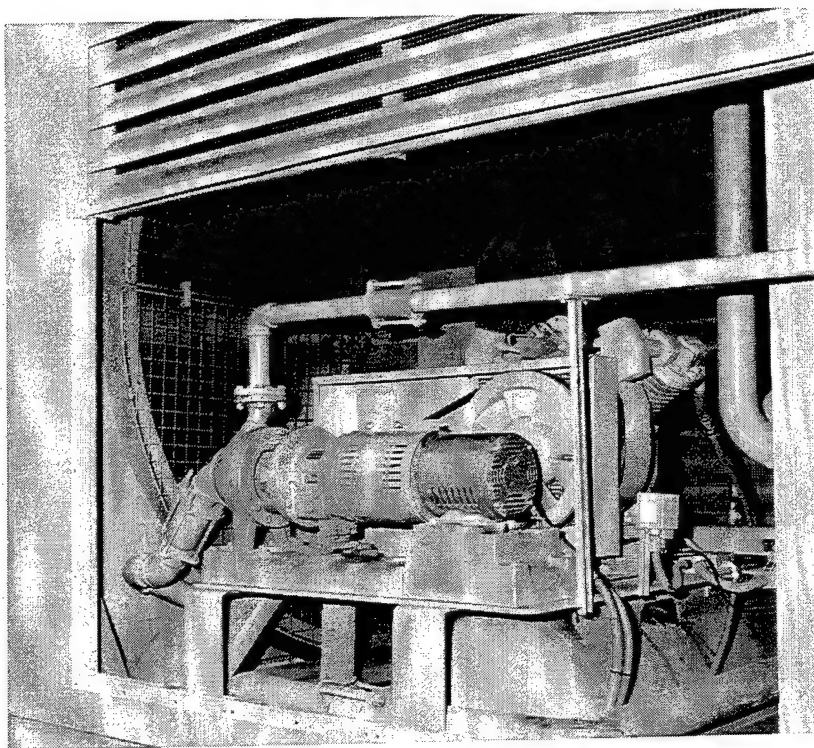
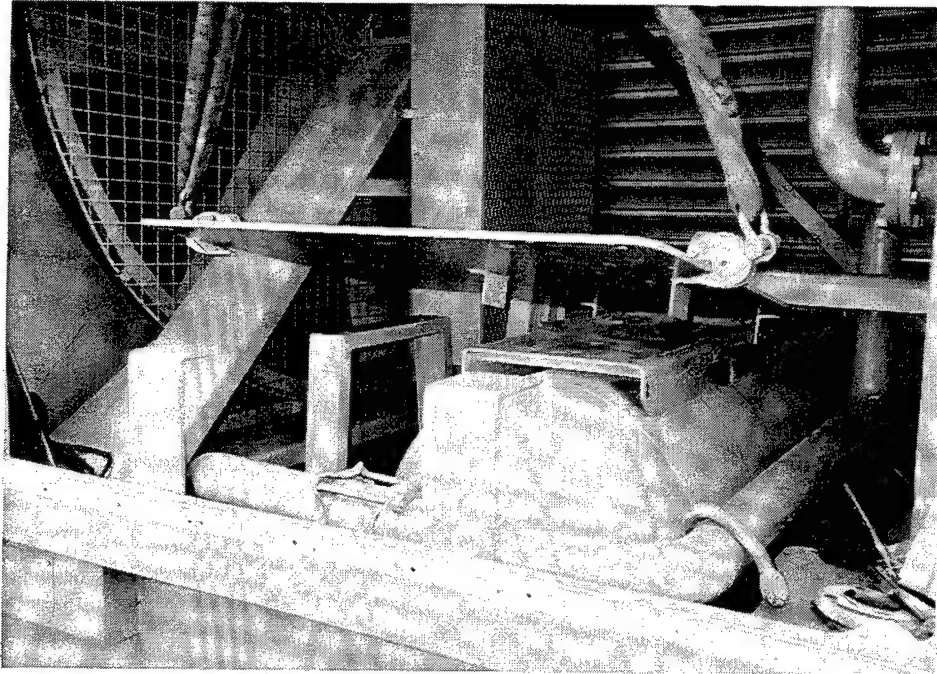
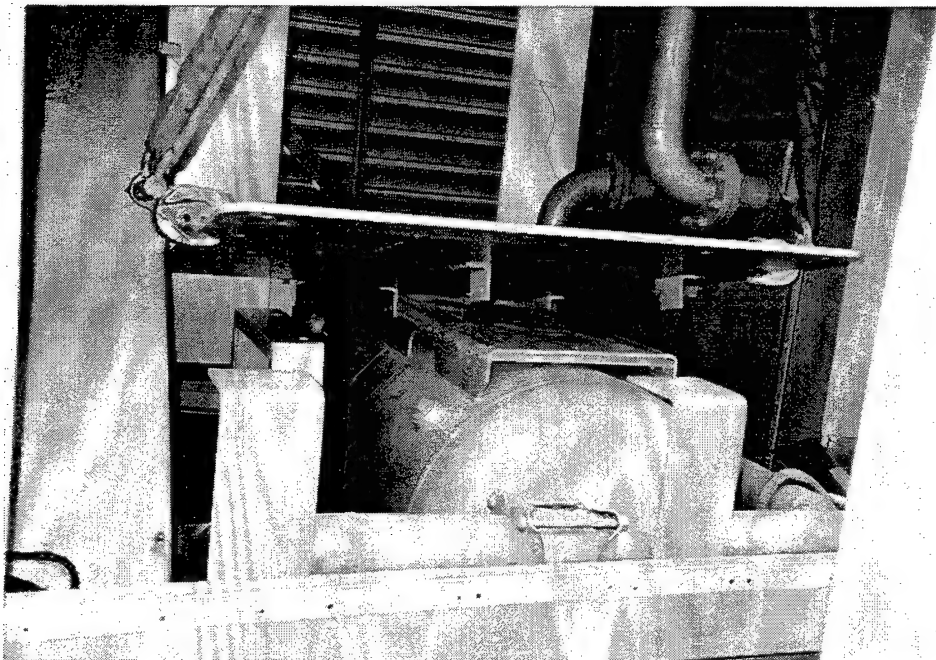


Figure 4-24. Mounting of air compressor and water pump.



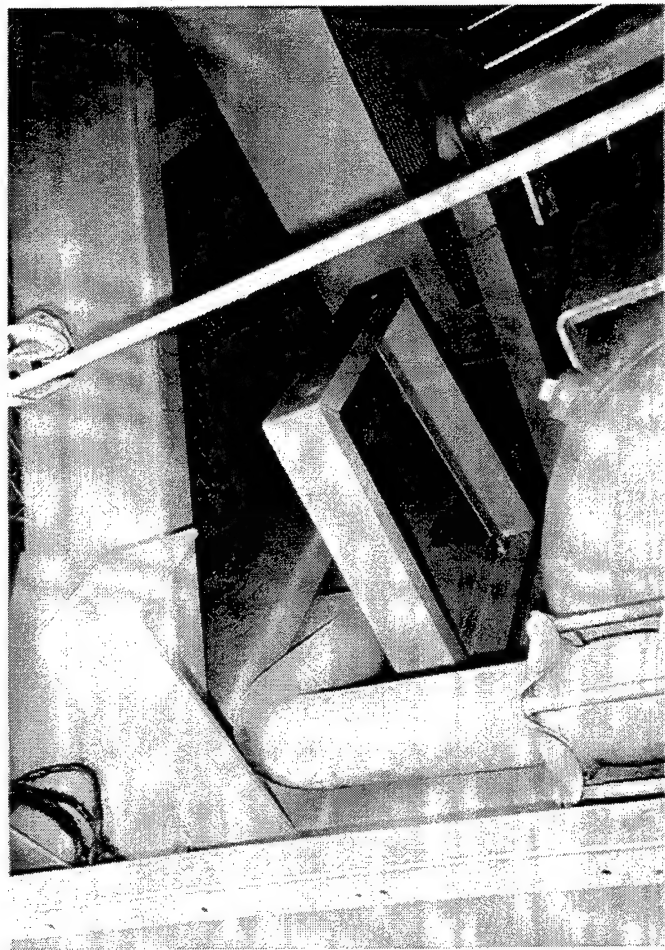
(a) Support legs, including compressed air tank with mounting brackets and channel iron support legs.



(b) View from opposite side.

Figure 4-25. Table for supporting air compressor and water pump.

(c) Closeup of channel iron support legs.



(d) Table bolted in place.

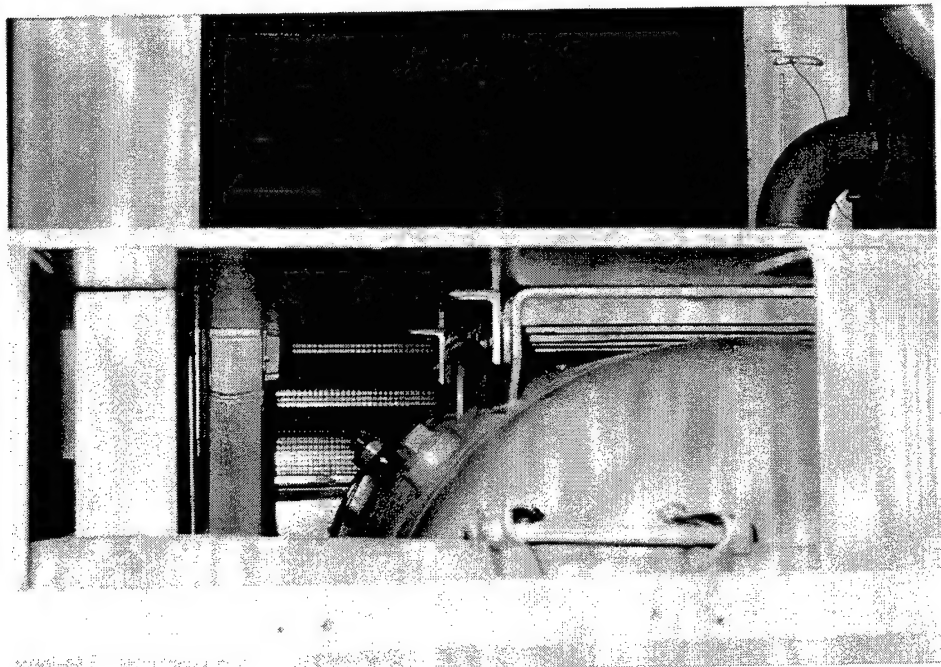
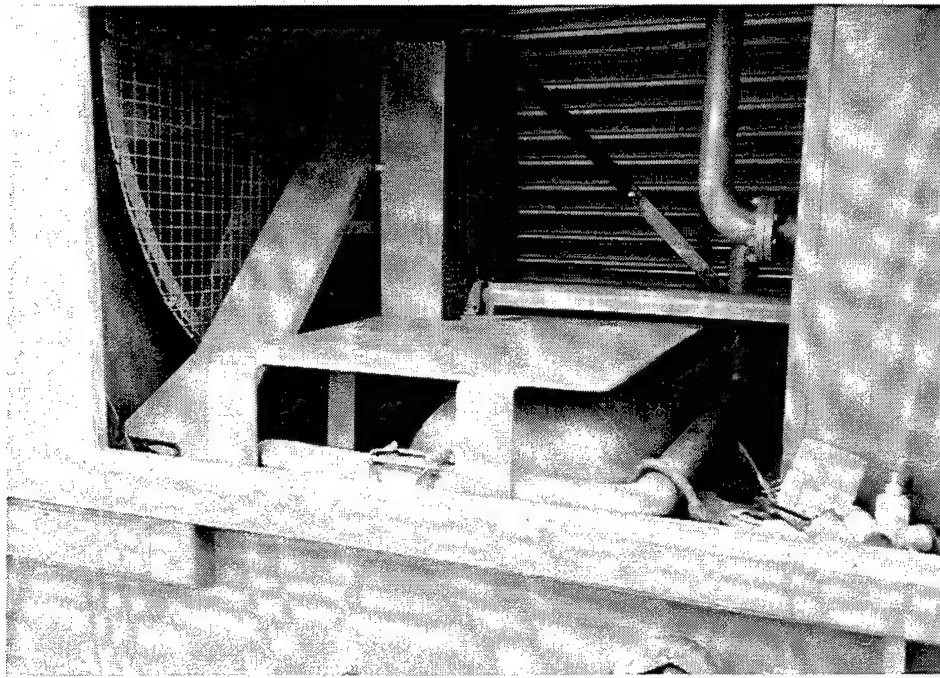
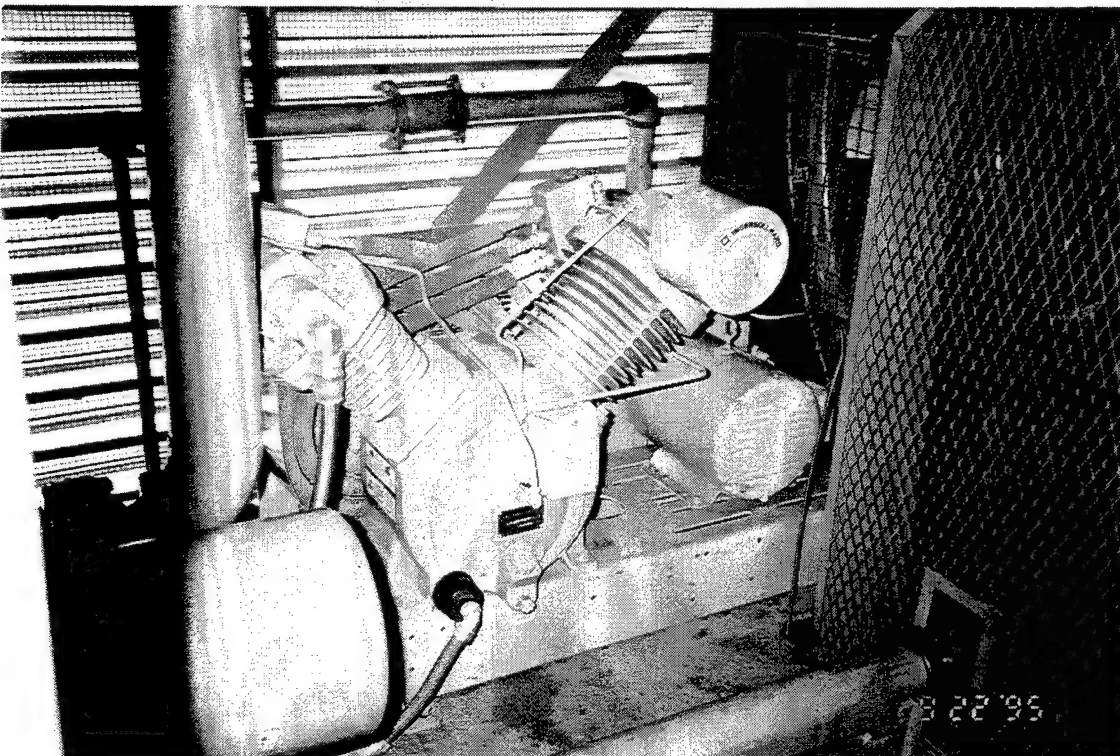


Figure 4-25. Table for supporting air compressor and water pump. (Cont'd.)





(e) Table installed.



(f) Inside view of new compressor after installation.

Figure 4-25. Table for supporting air compressor and water pump. (Cont'd.)



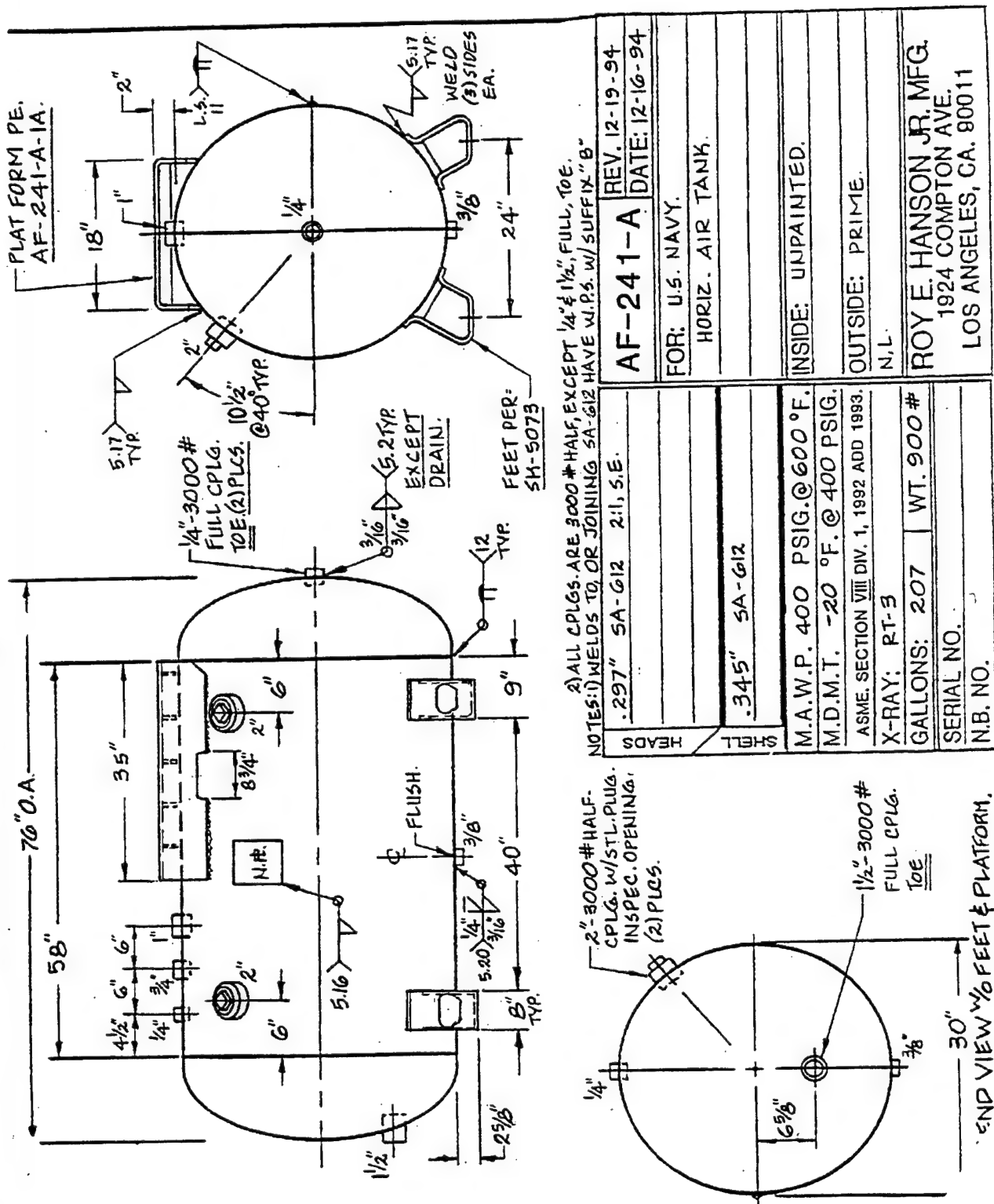
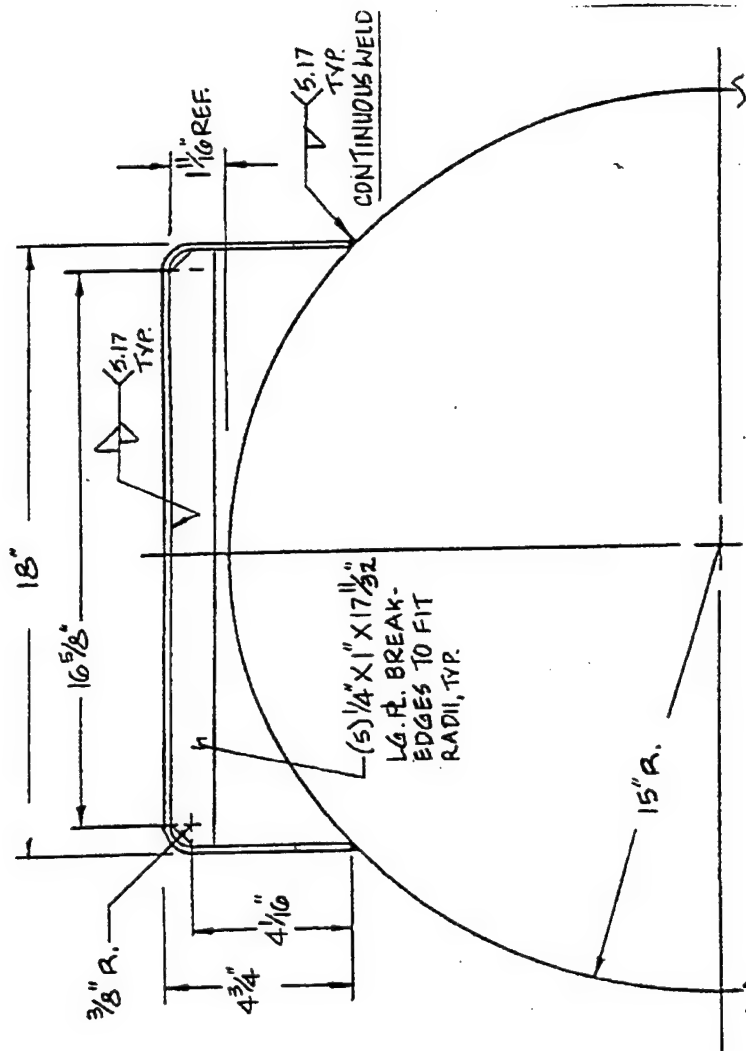
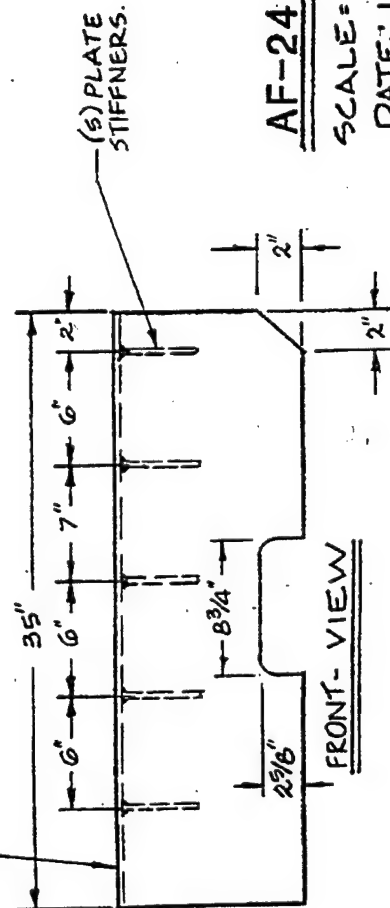


Figure 4-26. Specification for replacement compressed air storage tank.



M/F. - .313" X 26 7/16"  
X 35" LG. PL.



**AF-241-A-1A**

SCALE = NONE.

DATE: 12-16-94, N.L.

REV. 12-19-94

Figure 4-26. Specification for replacement compressed air storage tank. (Cont'd.)

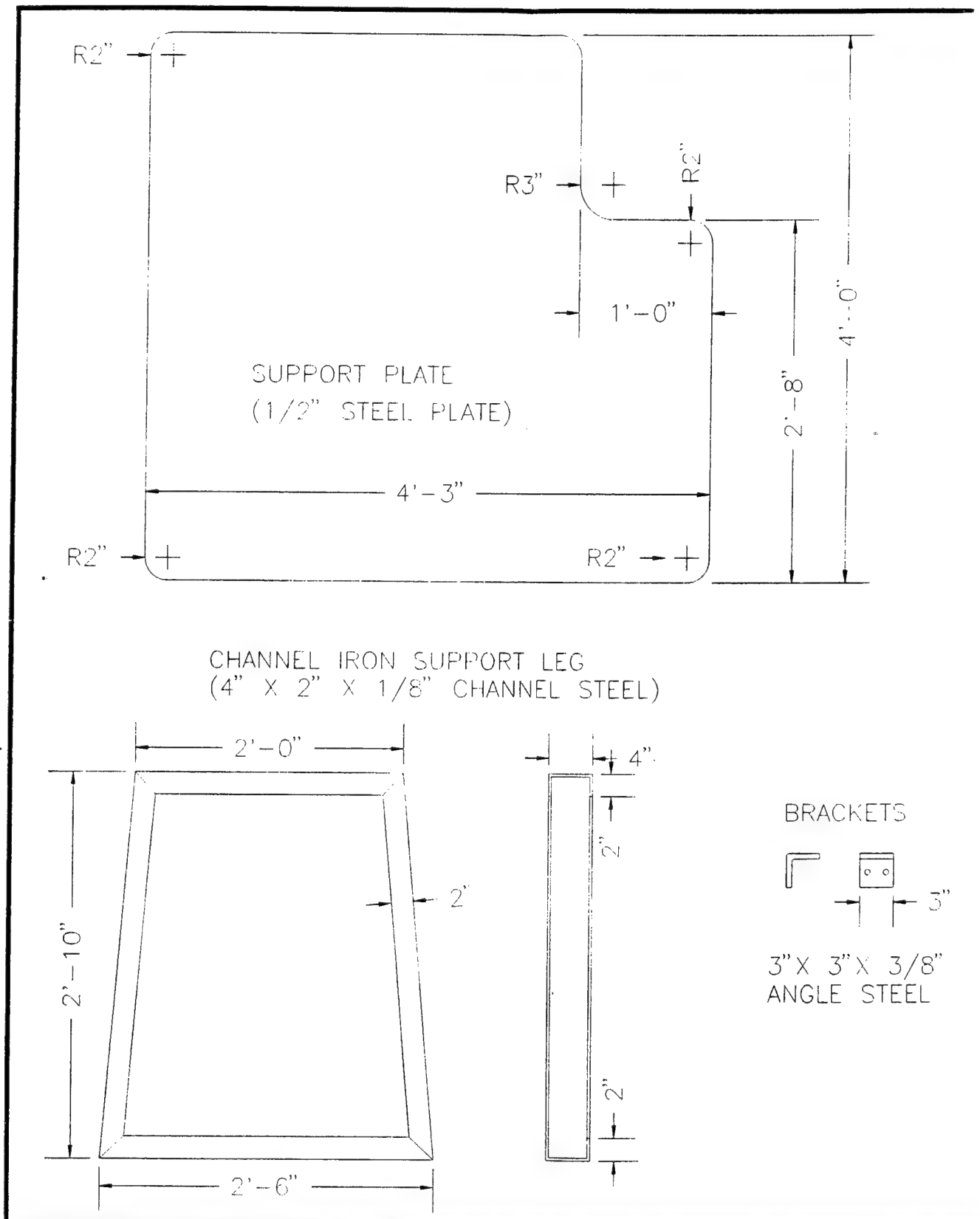


Figure 4-27. Specifications of tabl

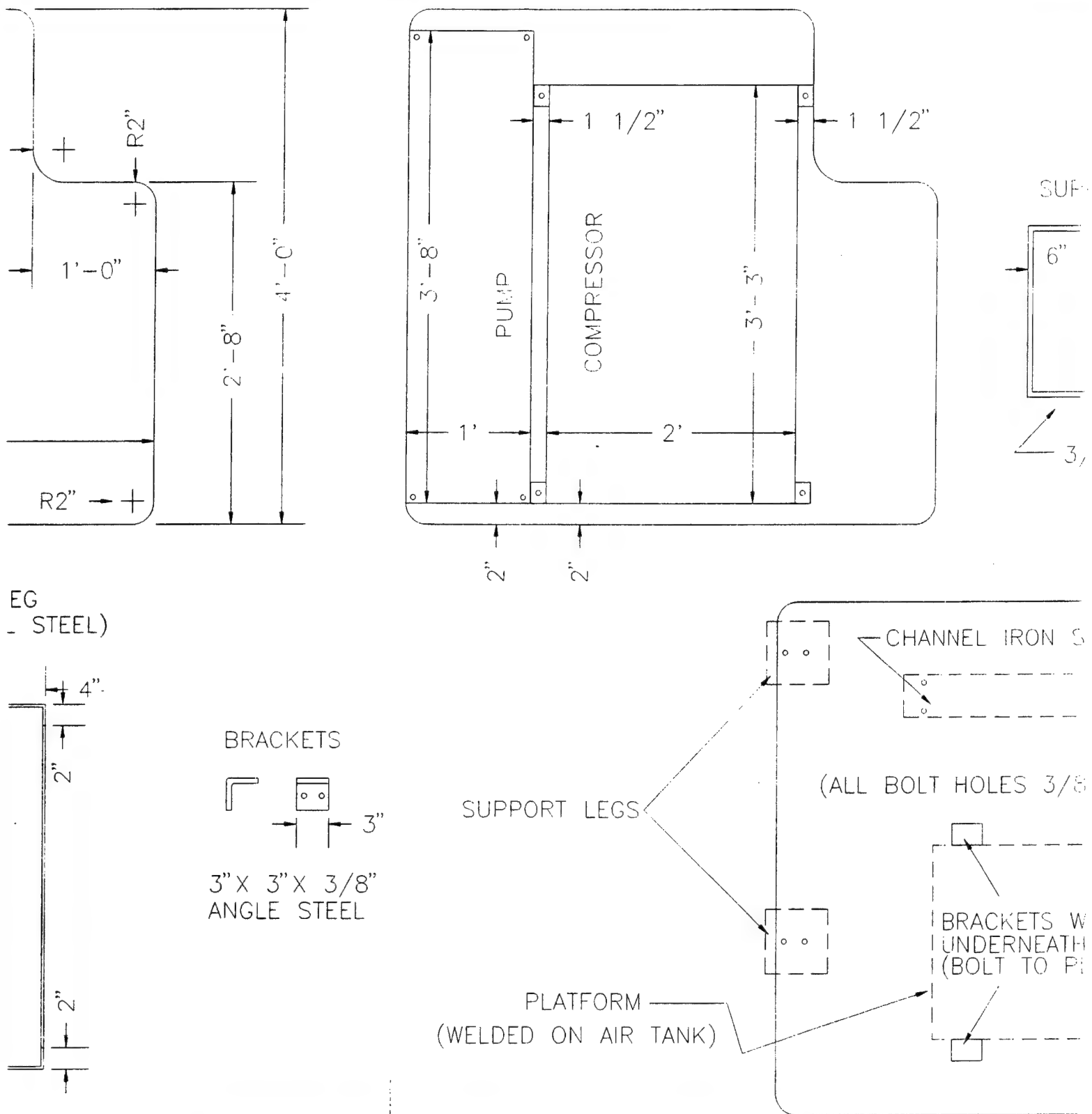
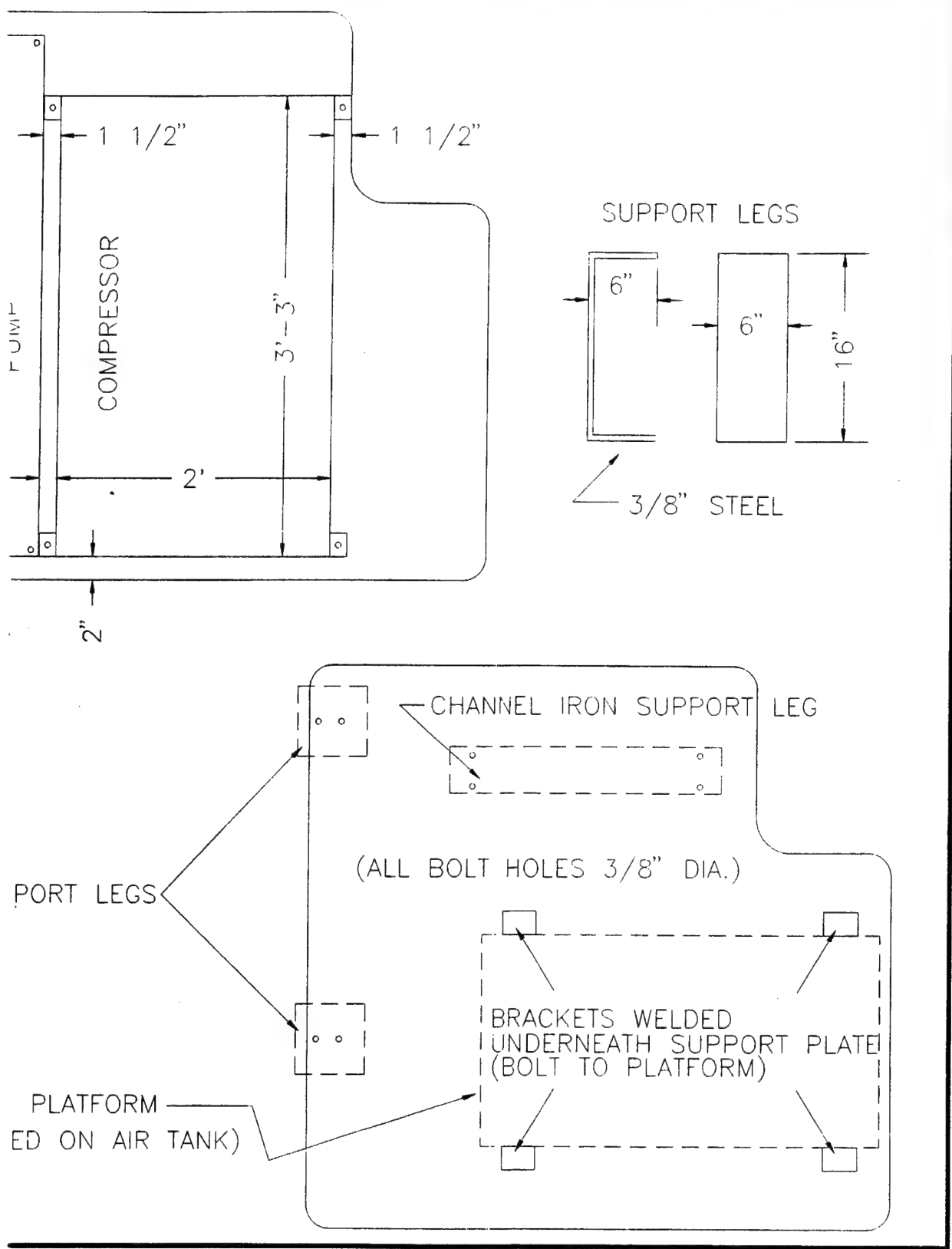
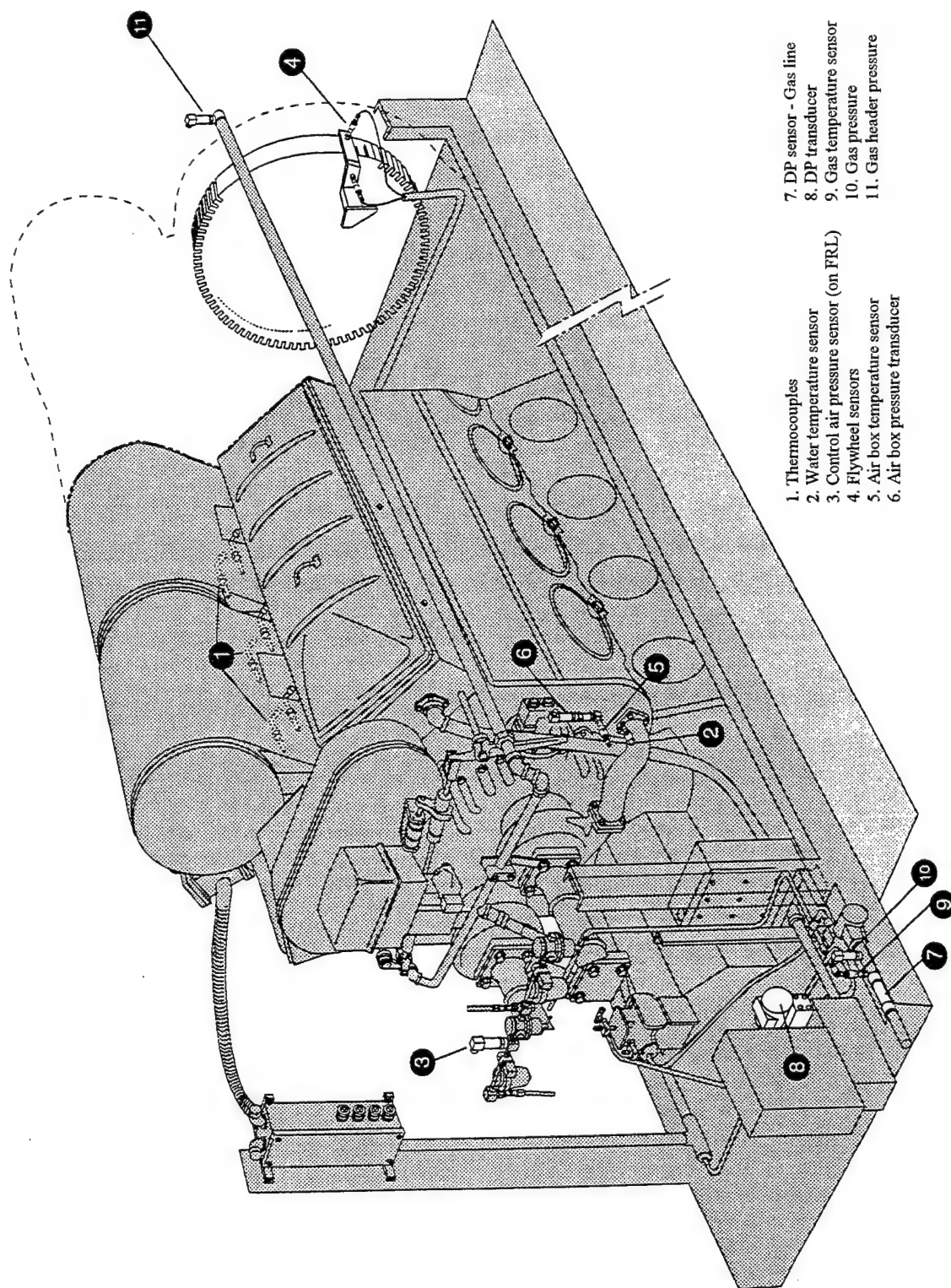


Figure 4-27. Specifications of table for pump and compressor support.

2



and compressor support.

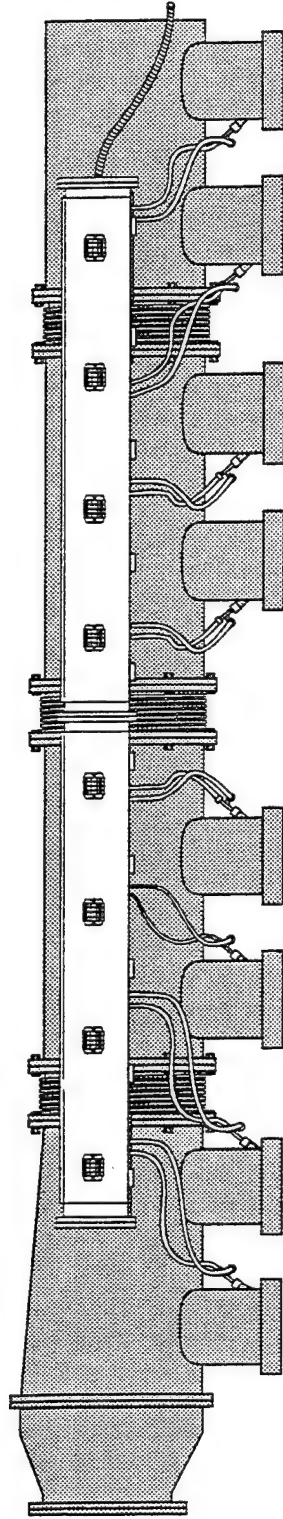


- |   |                           |
|---|---------------------------|
| 1. Thermocouples                        | 7. DP sensor - Gas line   |
| 2. Water temperature sensor             | 8. DP transducer          |
| 3. Control air pressure sensor (on FRL) | 9. Gas temperature sensor |
| 4. Flywheel sensors                     | 10. Gas pressure          |
| 5. Air box temperature sensor           | 11. Gas header pressure   |
| 6. Air box pressure transducer          |                           |

Figure 4-28. Sensors for dual fuel conversion.  
(Used by permission, Energy Conversions, Inc., U.S.A., 1996.)

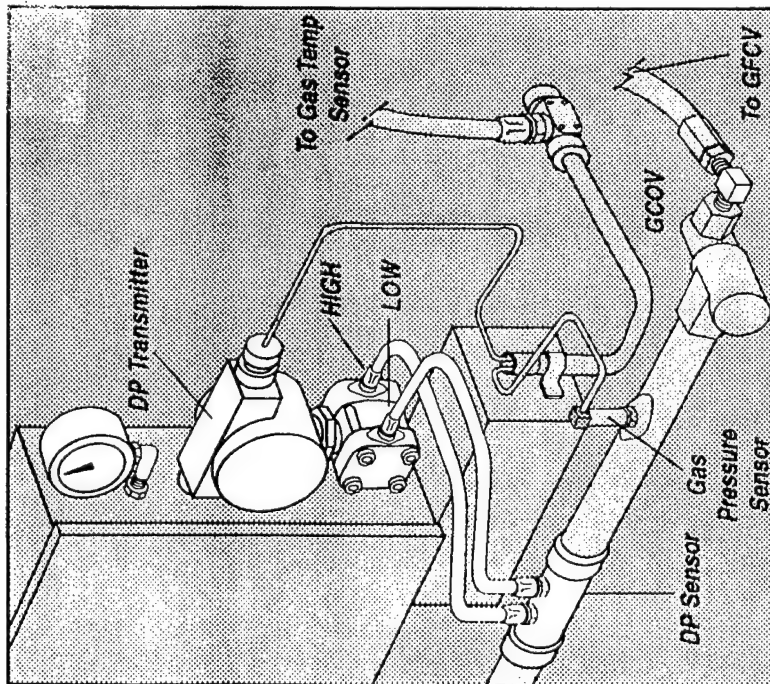


## Exhaust Conduit and Thermocouples

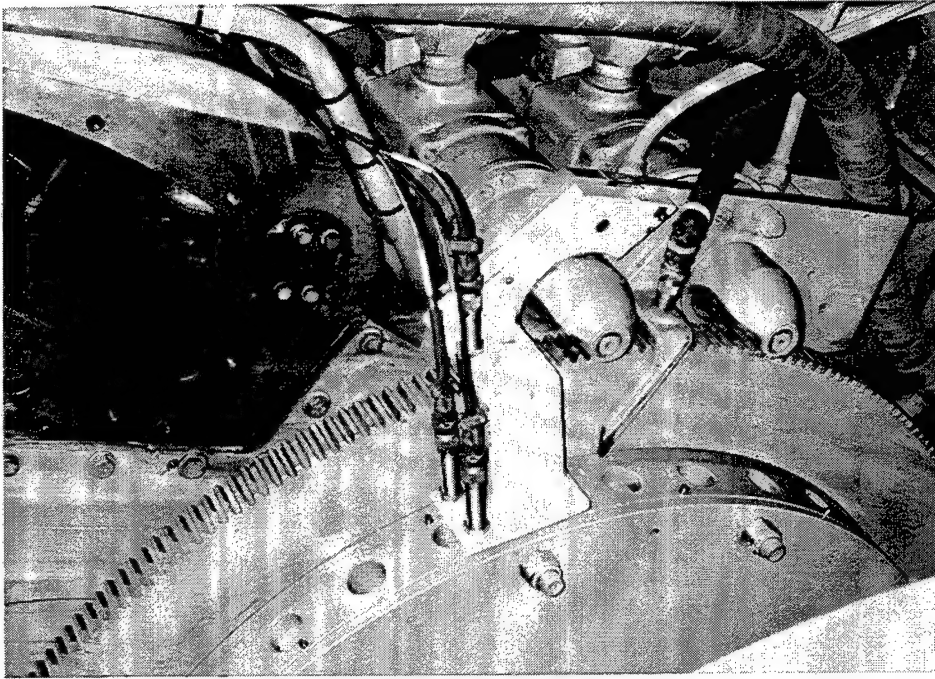


NOTE: All sensors face toward the center on all engines. Exceptions can be made if carefully planned.

Figure 4-29. Exhaust temperature measurements.  
(Used by permission, Energy Conversions, Inc., U.S.A., 1996.)



(a) NG metering sensors.



(b) Flywheel sensors on mounting bracket.

Figure 4-30. Dual fuel sensors.

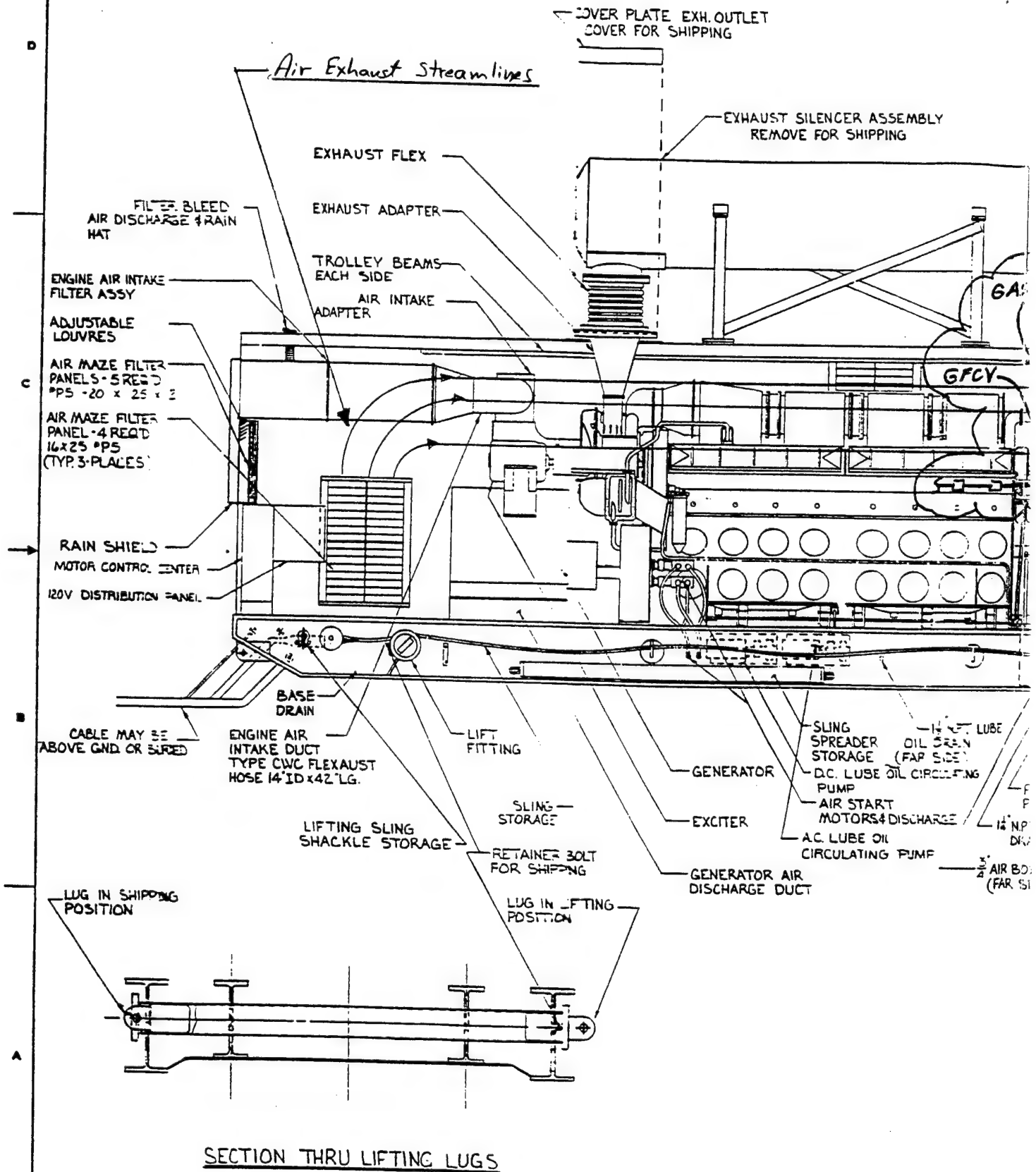
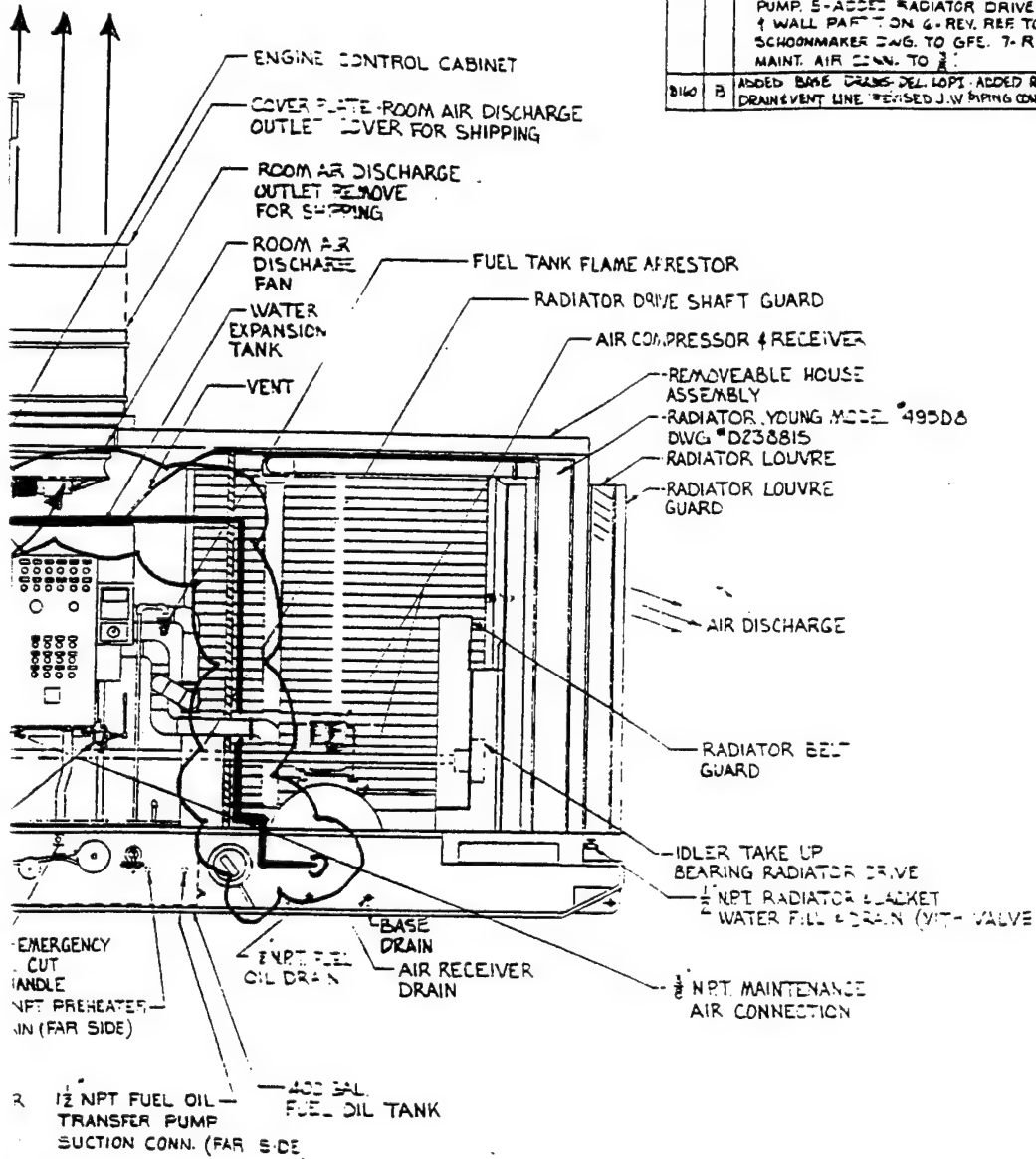


Figure 4-31. Cutaway side view of MU gas detectors and air flow  
(Used by permission, Energy Conversion)



Exhaust



REVISIONS				
REV.	DATE	DESCRIPTION	DATE	APPROVED
8039 A	7-17-81	1. REV. LOCATION OF FUEL PRIME PUMP, AUX. TURBO LE FILER, DRAIN CONN. 1/2 NPT MAINT. AIR CONN. & ASSOC. PIPING. 2. REV. ROOM AIR DISCHARGE FAN, AIR START MOTOR QTY. & CONN. 3-RELOCATED AC SOAKBACK PUMP 4-ADDED DC SOAKBACK PUMP 5-ADDED RADIATOR DRIVE SHAFT & WALL PARTITION 6-REV. REF TO SCHOONMAKER DWS. TO GFE. 7-REV. 1/2" MAINT. AIR CONN. TO 3.		
8140 B	8-13-81	ADDED BASE DRAIN DEL LOFT. ADDED RADIATOR DRAIN EVENT LINE REVISED J.W. PIPING CONFIGURATION		

ATTACHMENT 1

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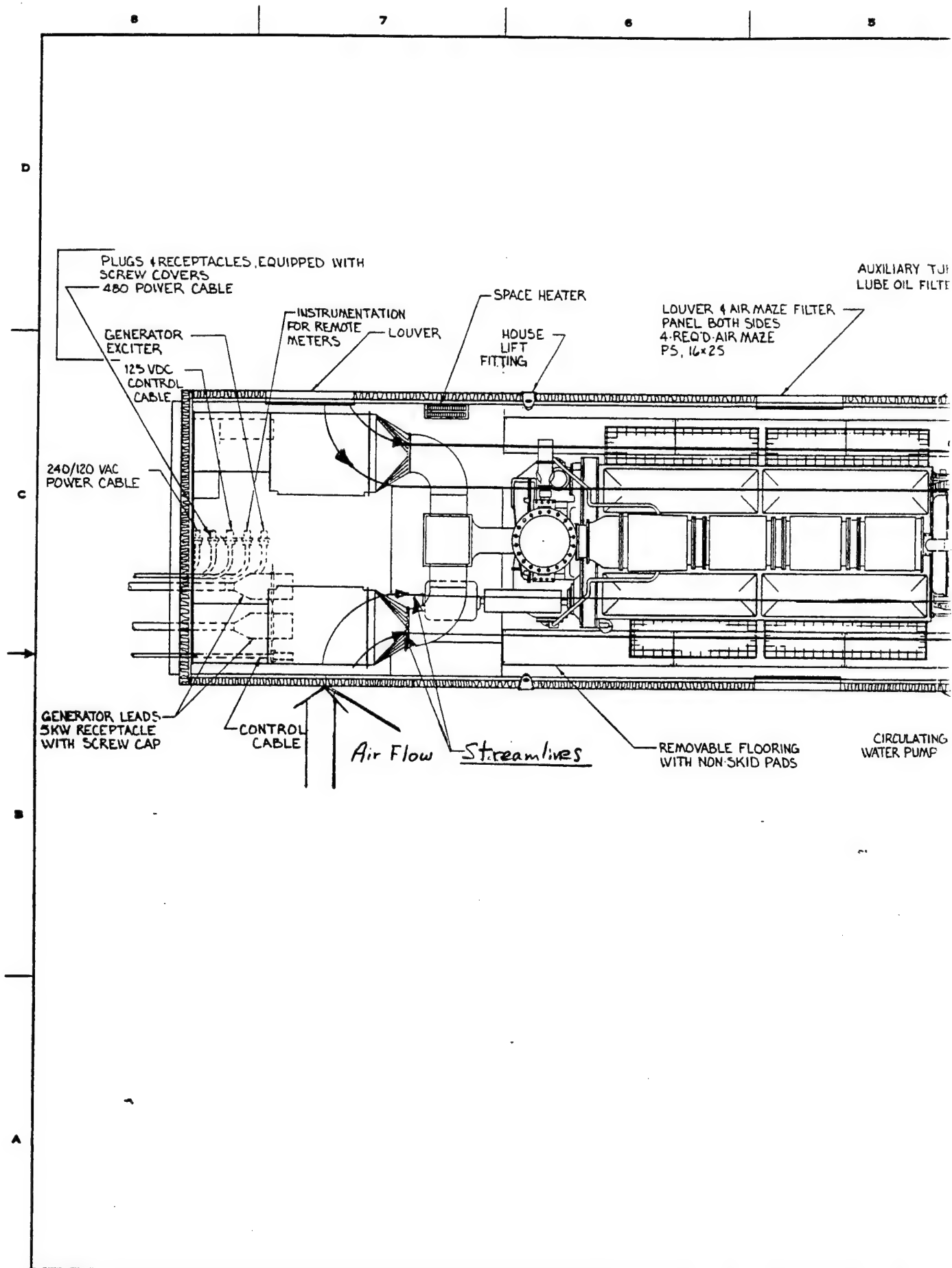


Figure 4-32. Cutaway top view of MU and air flow streamlines.  
(Used by permission, Energy)

①



LOUVER 4 AIR MAZE FILTER  
PANEL BOTH SIDES  
4-REQ'D-AIR MAZE  
PS, 16x25

AUXILIARY TURBO  
LUBE OIL FILTER

FUEL TRANSFER PUMP

LUBE OIL FILTERS

15KW PRE-HEATER  
JACKET WATER

FUEL FILTER

Exhauster

CIRCULATING  
WATER PUMP

SPACE  
HEATER

RADIATOR ROOM  
PARTITION

HINGED FLOOR PLATE

RADIATOR ROOM LOUVER

REMOVABLE FLOORING  
WITH NON-SKID PADS

■ Gas Detectors      --- Natural Gas Piping

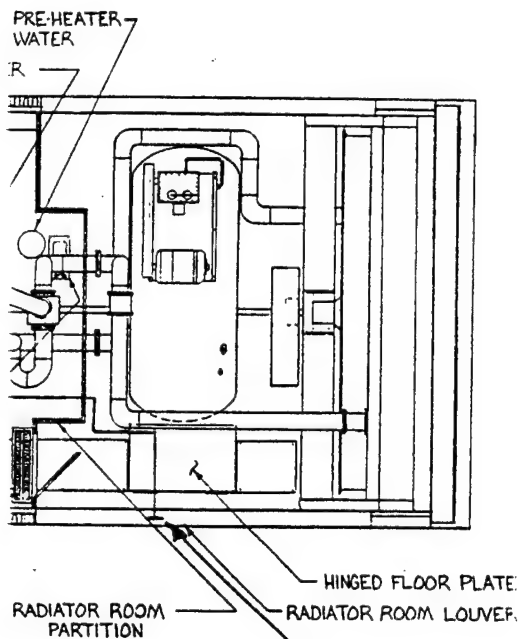
Figure 4-32. Cutaway top view of MUSE unit showing NG piping, gas detectors, and air flow streamlines.

(Used by permission, Energy Conversions, Inc., U.S.A., 1996.)

2

REVISIONS				
ZONE	LTR.	DESCRIPTION	DATE	APPROVED
8029	A	1-REV. POSITION OF FUEL TRANSFER PUMP & AUX. TURBO L.O. FILTER. 2-RMV. STEPS @ RADIATOR BELT GUARD. 3-ADDED RADIATOR DRIVE SHAFT. 4-ADDED ADDITIONAL INTCON CABLES	7-16-81	J. Humpal
8187	B	RELOCATED CIRCULATING WATER PUMP; ADDED PLUG IDENTIFICATION; REVISED J.W. PIPING CONFIGURATION	08-14-81	M. Humpal

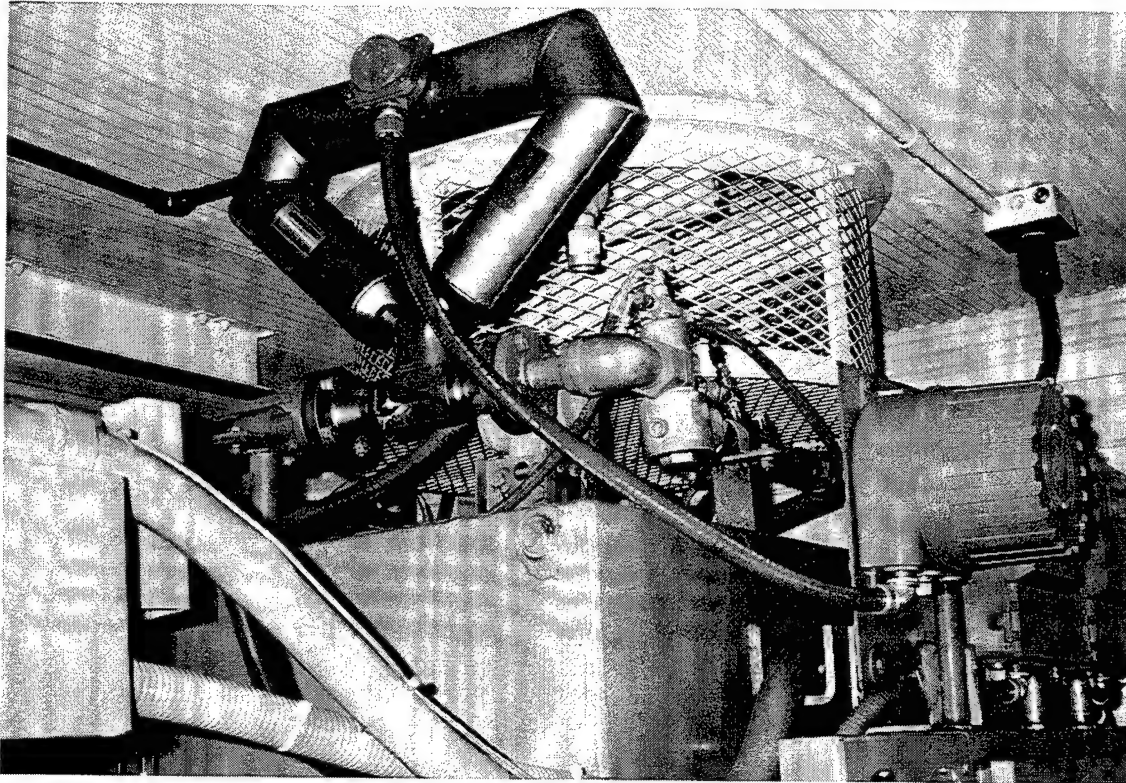
ER PUMP  
TERS



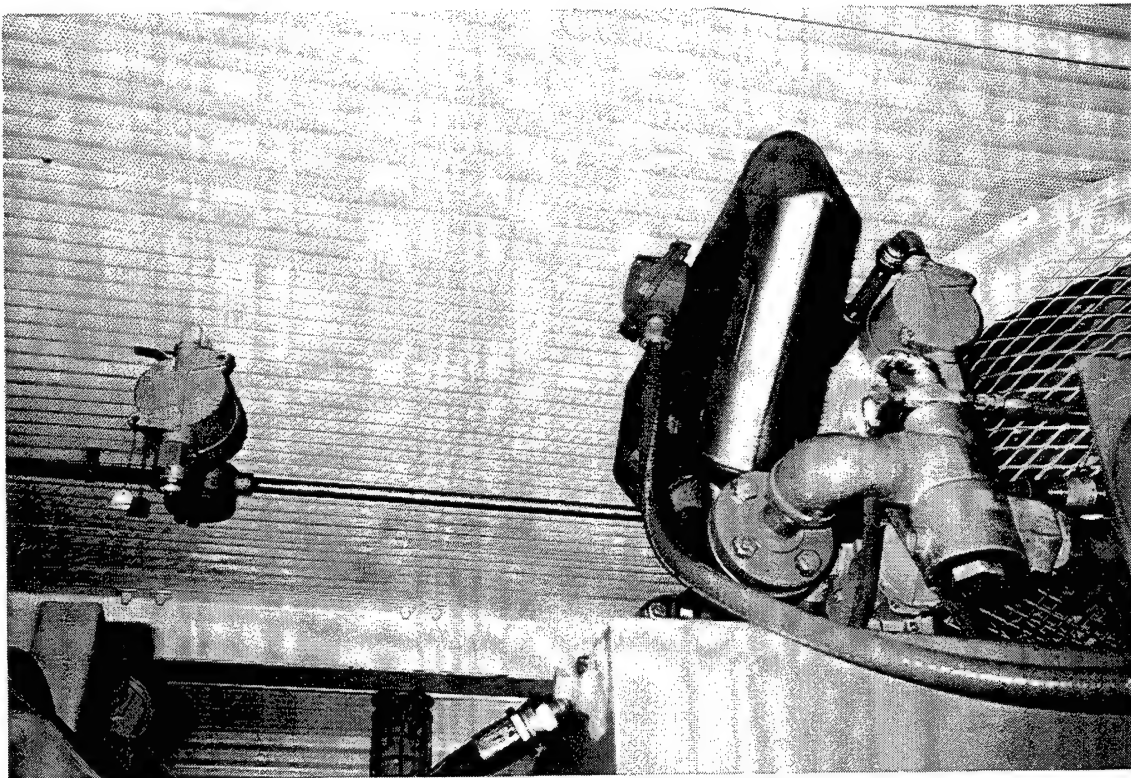
ITEM NO.	QTY.	DESCRIPTION	CODE	DATE	QTY.
LIST OF MATERIAL OR PARTS LIST					
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES		CONTRACT NO. <b>N62472-80-C-1648</b> INVO. <b>6039</b> <b>DAVISVILLE</b> DATE <b>3/4/81</b> CHECKED BY <b>J. Humpal</b> <b>3/31/81</b> DRAWN BY <b>M. Humpal</b> <b>2-23-81</b>			
TOLERANCES ON FRACTIONS DECIMALS ANGLES		<b>POWER SYSTEMS DIVISION</b> <b>MORRISON-KNUDSEN COMPANY, INC.</b> ROCKY MOUNT, NORTH CAROLINA 27861			
MATERIAL		TITLE <b>GENERAL ARRANGEMENT</b> <b>1500 KW, 4160/2400V 60Hz</b> <b>1200 KW, 3600/2100V 50Hz</b> <b>3 PHASE 0.8 PF.</b>			
TREATMENT		DESIG. ACTIVITY APPROVAL <b>D 6E148 6039D02001</b>			
USED ON		SCALE <b>1/2" = 1'-0"</b>			
NEXT ASBY		SHEET <b>2 OF 2</b>			
FINAL ASBY		REV. <b>B</b>			
QTY. REQD.					

pipng, gas detectors,

3

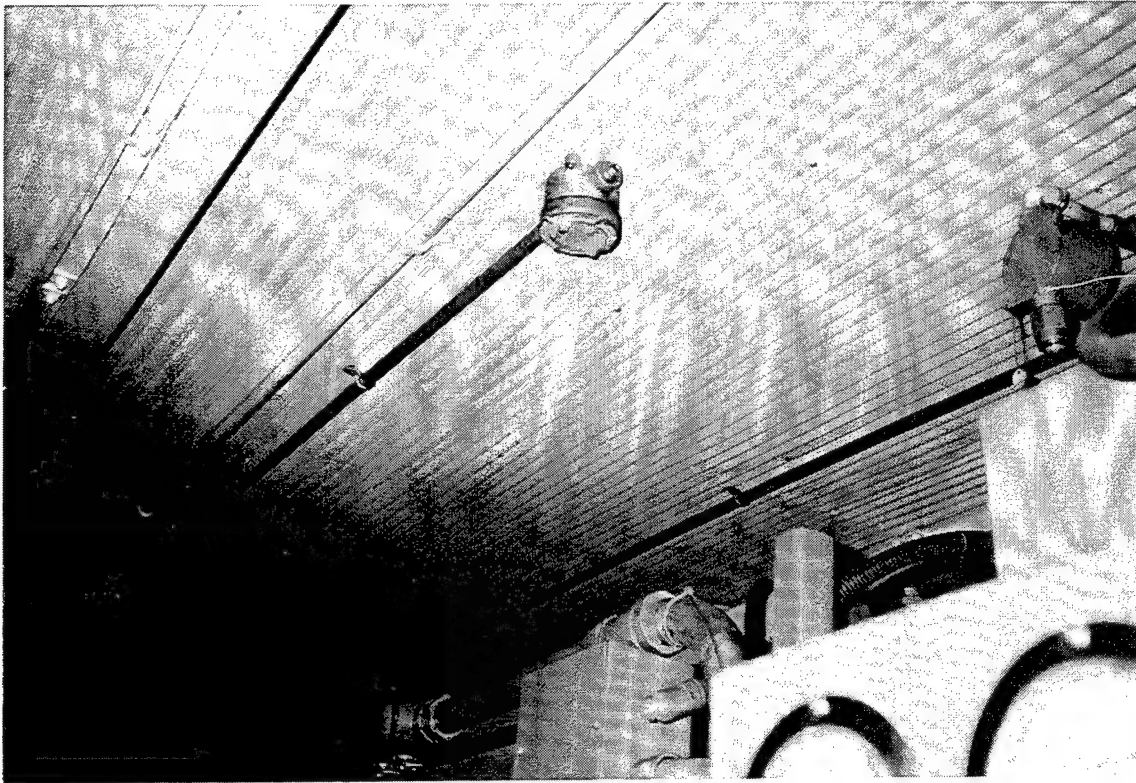


(a) Engine compartment exhaust blower.

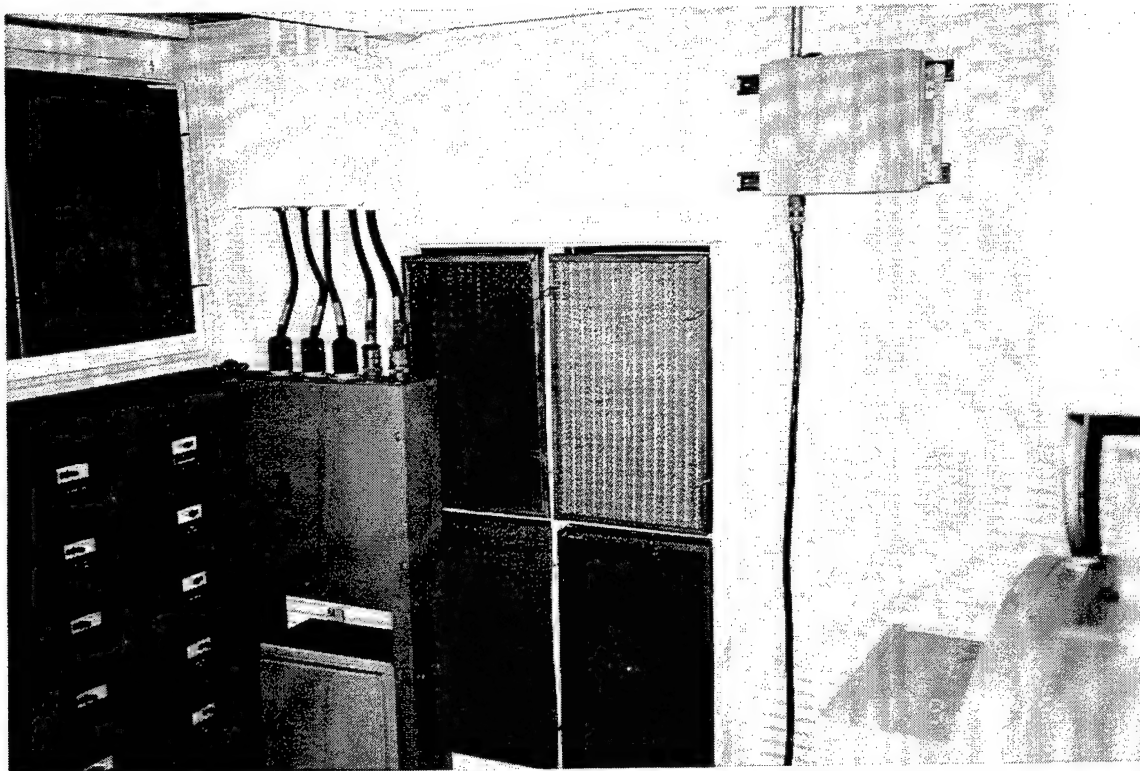


(b) Explosive gas detectors.

Figure 4-33. Photographs of safety equipment.

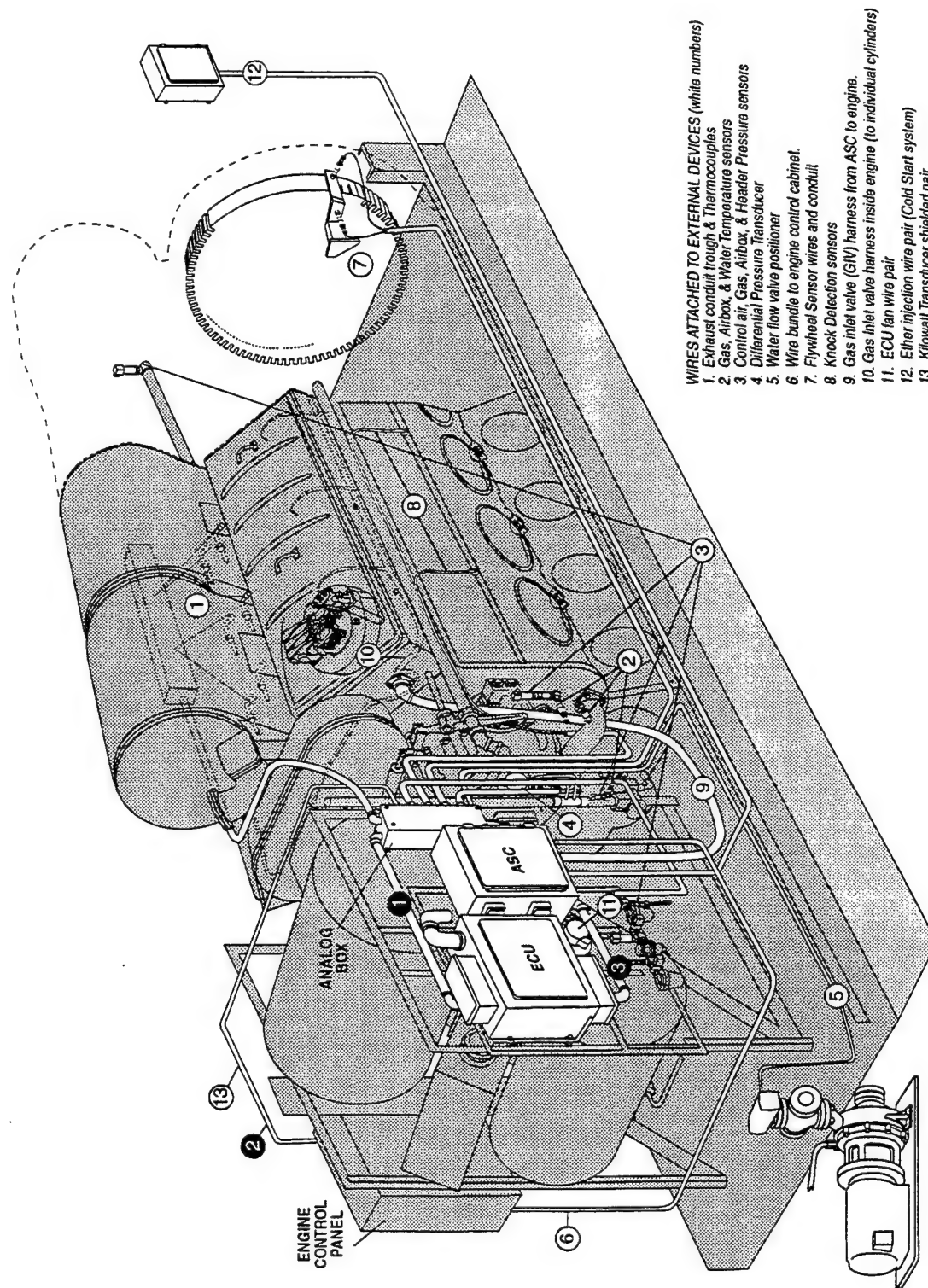


(a) Explosive gas detectors and conduit to junction box.



(b) Junction box/J connector for removal of housing.

Figure 4-34. Photographs of safety equipment.



- WIRES ATTACHED TO EXTERNAL DEVICES (white numbers)**
1. Exhaust conduit trough & Thermocouples
  2. Gas, Airbox, & Water Temperature sensors
  3. Control air, Gas, Airbox, & Header Pressure sensors
  4. Differential Pressure Transducer
  5. Water flow valve positioner
  6. Wire bundle to engine control cabinet
  7. Flywheel Sensor wires and conduit
  8. Knock Detection sensors
  9. Gas inlet valve (GIV) harness from ASC to engine.
  10. Gas inlet valve harness inside engine (to individual cylinders)
  11. ECU fan wire pair
  12. Ether injection wire pair (Cold Start system)
  13. Kilowatt Transducer shielded pair

Figure 4-35. Pictorial view of gas system controllers and electrical conduits.

(Used by permission, Energy Conversions, Inc., U.S.A., 1996.)



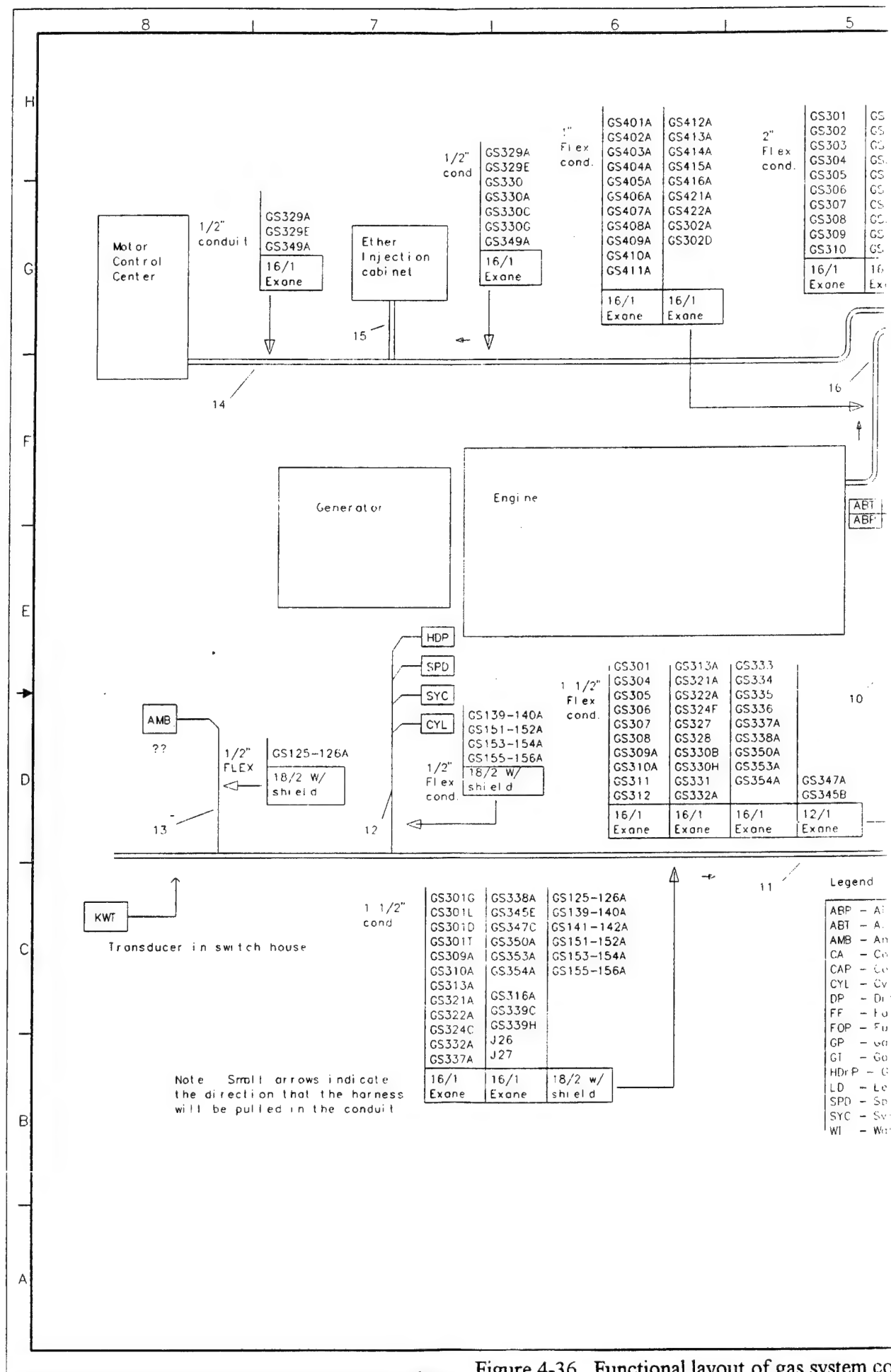
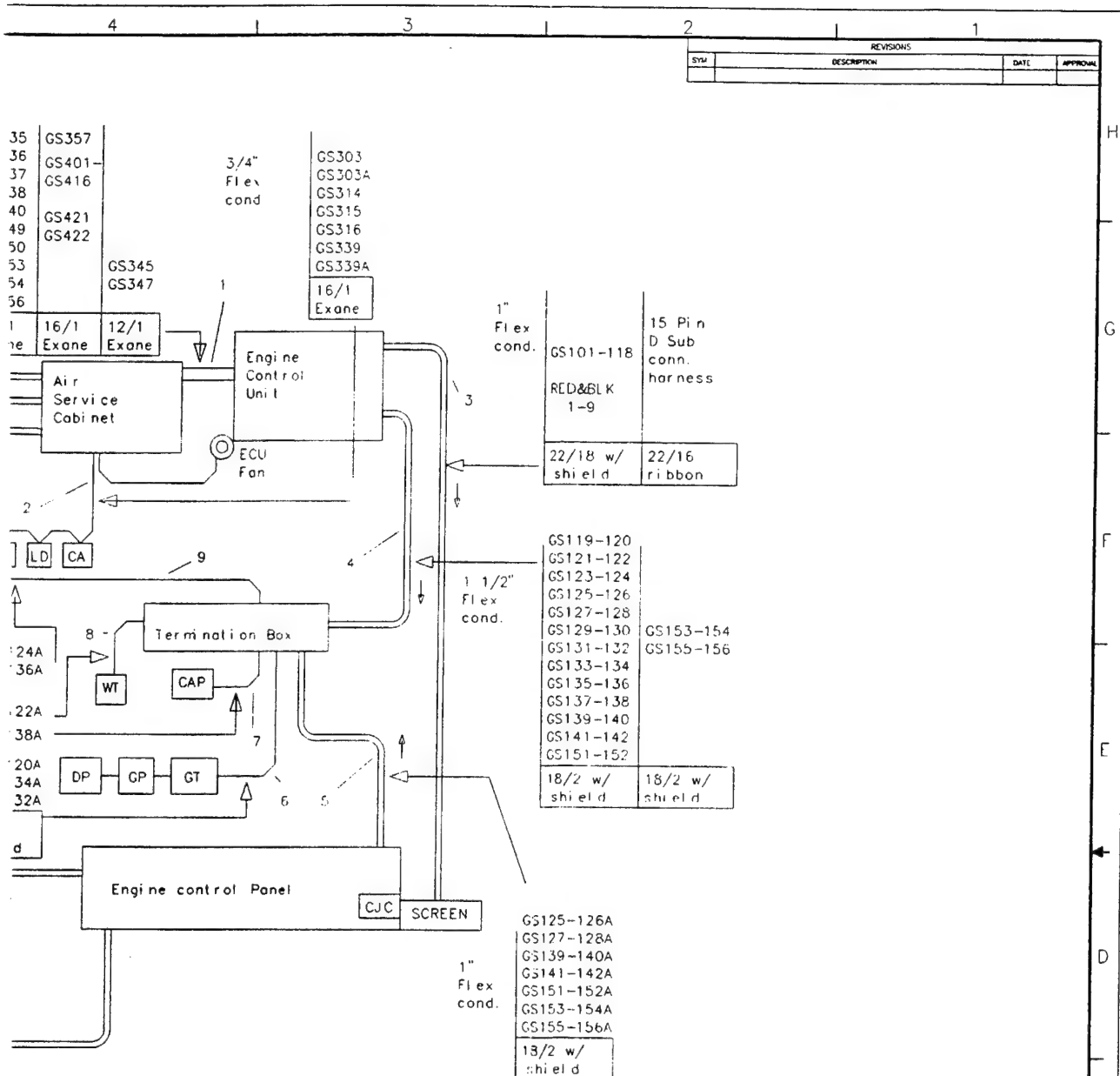


Figure 4-36. Functional layout of gas system co  
(Used by permission, Energy Conver







Gas System conduit and wiring			
	Draw. No.	USNSYS6.GCD	REV. A
	Part #		11/21/96
	Application		Drawn by SPJ
	Date	10/27/94	pg 6 of 14
Energy Conversions Inc.			

QUANTITY FOR EACH ASSEMBLY		ITEM NO.	PART NO.	DESCRIPTION	MATERIAL
PARTS LIST					
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN FEET AND/OR INCHES		DEPARTMENT OF THE NAVY NAVAL FACILITIES ENGINEERING SERVICE CENTER PORT HUENEME, CALIFORNIA 93043			
TOLERANCES: X DECIMALS XX DECIMALS XXX DECIMALS FRACTIONS ± 1/16" ANGLES ± 0.5°		DUEL FUEL 1500 KW CONVERSION OF DIESEL POWER PLANT SCHEMATIC OF GAS CONVERSION SYSTEM GAS SYSTEM CONDUIT AND WIRING			
PART: [ ] NEXT ASSY: [ ]		APPROVED: [ ] DATE: [ ] COMMANDING OFFICER: [ ] APPROVED: [ ] DATE: [ ] FOR COMMANDER, NAVFAC			
		SIZE: F 80091 SCALE: NONE		NAVFAC DRAWING NO. CONSTR CONTR NO. SPEC: [ ] SHEET: 1 OF 14	

# System Block Diagram

of electrical control signals for

Gas conversion system on EMD 645 Mobil generators

Energy Conversions Inc. 10/27/94

Dwg. USNBLOK.GCD



## Analog signals

Gas Temperature	
Water Temperature engine	
Air Box Temperature	
Ambient Temperature	
CJC temp compensation	
Spere	
Differential Pressure gas	
Gas Pressure supply	
Air Box Pressure	
Control Air Pressure	
Gas Header Pressure	
Kilowatts	
Exhaust temperature cylinders 1-16	
Engine Speed	
Crankshaft position	
Cylinder pulses	

Engine  
Control  
Unit

Screen data display and  
Operator diagnostic  
interface

Gas inlet valve timing  
signals. cylinders 1-16

## Engine modulation signal

Air Throttle PWM signal

## Digital Output signal

DCR Diesel Control Ram
R1-Gas run
R2
R3
Engine Run
After Cooler Pump
Cold Start

Digital inputs

Air Box Pressure	
Control Air Pressure	
Gas Headder Pressure	
Kilowatts	
Exhaust temperature cylinders 1-16	
Engine Speed	
Crankshaft position	
Cylinder pulses	

# Digital inputs

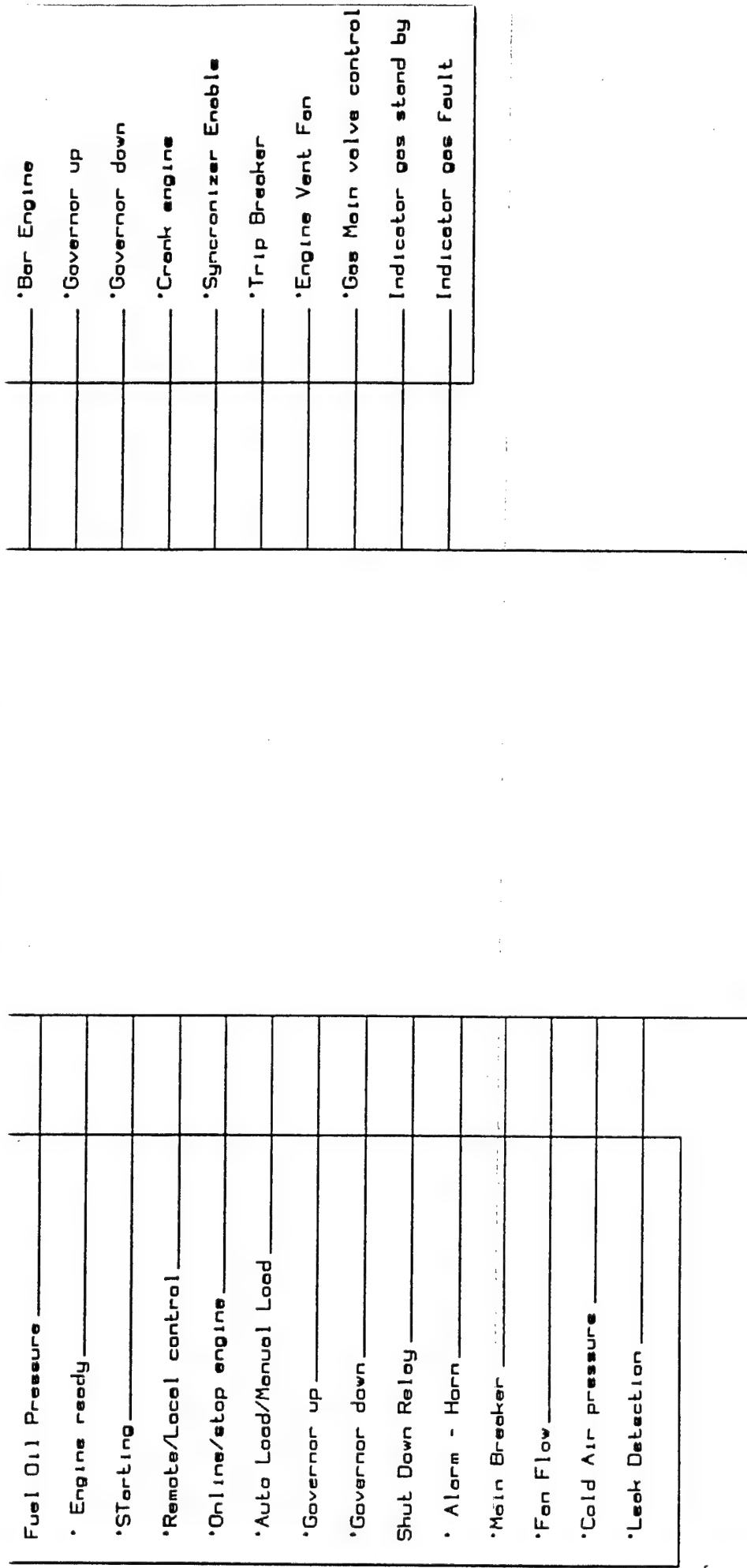
Gas operate	
VTS gas valve temp limit	
Fuel Oil Pressure	
• Engine ready	
• Starting	
• Remote/Local control	
• Online/stop engine	
• Auto Load/Manual Load	
• Governor up	
• Governor down	
Shut Down Relay	
• Alarm - Horn	
• Main Breaker	
• Fan Flow	
• Cold Air pressure	
• Leak Detection	

# Engine modulation signal

## Air Throttle PWM signal

## Digital Output signal

DCR Diesel Control Ram	
R1-Gas run	
R2	
R3	
Engine Run	
After Cooler Pump	
Cold Start	
• Pre Lube	
• Alarm - Horn	
• Bar Engine	
• Governor up	
• Governor down	
• Crank engine	
• Synchronizer Enable	
• Trip Breaker	
• Engine Vent Fan	
• Gas Main valve control	
Indicator gas stand by	
Indicator gas fault	



signals applied for automated remote operation

Figure 4-37. Electrical block diagram of engine control unit (ECU).  
(Used by permission, Energy Conversions, Inc., U.S.A., 1996.)

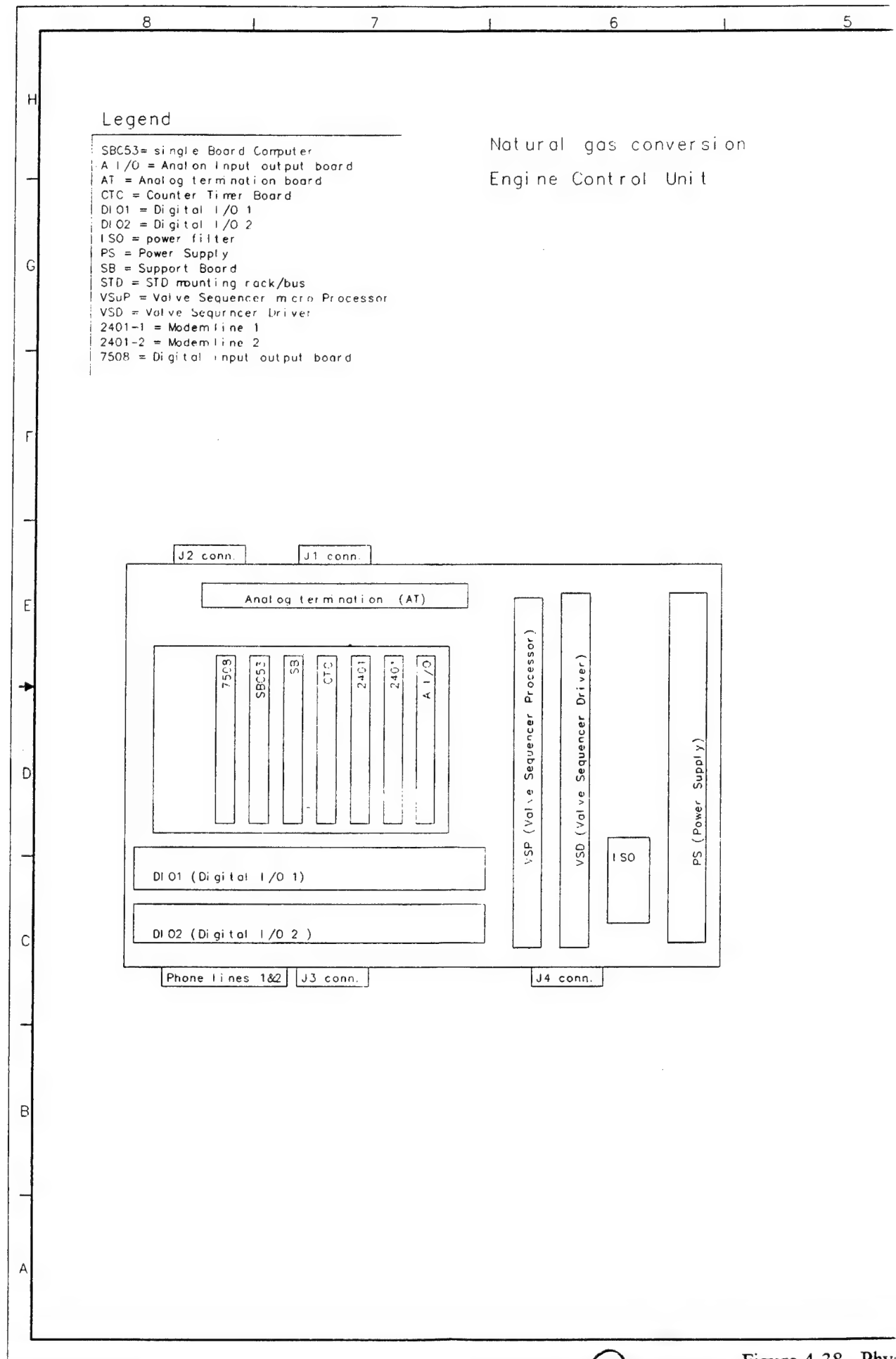


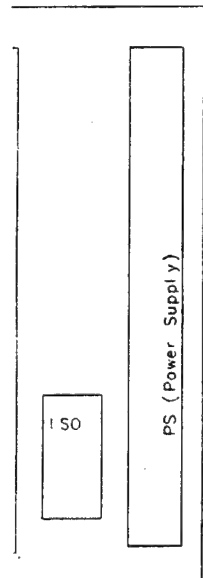
Figure 4-38. Physical layout of the control unit.  
 (Used by permission, E)



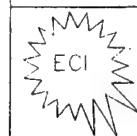
gas conversion  
ontrol Unit

# Ribbon cable connection list

Boards	Connectors	Conn. to
SBC53	J1	2401 J&2
	J2	SB J4
	J3	SB J5
A I/O	J1	AT J3
	J2	AT J4
AT	J1	External harness
	J2	5 discrete wires
	J3	A I/O J1
	J4	A I/O J2
	J5	CTC J1
CTC	J1	AT J5
	J2	SB J1
D I/O 1	J1	7508 J1
D I/O 2	J1	7508 J2
PS	J1	14 discrete wires
SB	J1	ECU conn. J2
	J2	CTC J2
	J3	5 discrete wires
	J4	SBC J2
	J5	SBC J3
VSD	J1	VSuP J2
	J2	ECU J4
VSuP	J1	6 discrete wires
	J2	VSD J1
2401-1	J1	Phone 1
	J2	SBC J1
2401-2	J1	Phone 2
	J2	JUNE 2401-1 J2
7508	J1	D I/O1 J1
	J2	D I/O2 J1



## Schematic of Navy Engine Control Unit



Draw. Name	USNECU1.GCD	REV.	A
Part #			1/17/95
Application		Dwn. by	SPJ
Date	2/11/94	pg.	13 of 14

Energy Conversions Inc.

QUANTITY FOR EACH ASSEMBLY		ITEM NO.	PART NO.	DATE
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN FEET AND/OR INCHES		PROJ. NO. USNECU1.gcd		
TOLERANCES: X DECIMALS XX DECIMALS XXX DECIMALS FRACTIONS ± 1/16" ANGLES ± 0.5°		DES. BY DW. BY BRANCH HEAD CHK. BY SATISFACTORY TO		
PART DASH NO.	NEXT ASSY	APPROVAL	DATE	SCALE
		FOR COMMANDER, NAVFAC	DATE	NOTES


Figure 4-38. Physical internal layout of ECU.  
(Used by permission, Energy Conversions, Inc., U.S.A., 1996.)

- DO NOT SCALE



1 cable connection list

	Connectors	Conn. to
	J1	2401 1&2
	J2	SB J4
	J3	SB J5
	J1	AT J3
	J2	AT J4
	J1	External harness
	J2	5 discrete wires
	J3	A I/O J1
	J4	A I/O J2
	J5	CTC J1
	J1	AI J5
	J2	SB J1
	J1	7508 J1
	J1	7508 J2
	J1	14 discrete wires
	J1	ECU conn. J2
	J2	CTC J2
	J3	5 discrete wires
	J4	SBC J2
	J5	SBC J3
	J1	VSP J2
	J2	ECU J4
	J1	6 discrete wires
	J2	VSD J1
	J1	Phone 1
	J2	SBC J1
	J1	Phone 2
	J2	JUMP 2401 J2
	J1	D I/O1 J1
	J2	D I/O2 J1



Draw. Name

USNECU1 GCD

Part #

Application

Date

2/11/94

REV

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1/17/95

Dwn. by

SPJ

pg.

13

of 14

Energy Conversions Inc.

QUANTITY FOR EACH ASSEMBLY		ITEM NO	PART NO	DESCRIPTION	MATERIAL
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN FEET AND/OR INCHES		PARTS LIST			
TOLERANCES: X DECIMALS XX DECIMALS XXX DECIMALS FRACTIONS ±1/16" ANGLES ±0.5°		<div> <div>PROD NO</div> <div>USNECU1.gcd</div> </div> <div> <div>DES XX</div> <div>OR F DELLABRERA</div> </div> <div> <div>CHN XX</div> <div>BROWN HEAD R.MALP</div> </div> <div> <div>DRY 20</div> <div>SATISFACTORY TO</div> </div> <div> <div>APPROVED</div> <div>DATE</div> </div> <div> <div>COMMANDED OFFICER</div> <div>DATE</div> </div> <div> <div>FOR COMMANDER NAVFAC</div> </div> <div> <div>DEPARTMENT OF THE NAVY</div> <div>NAVAL FACILITIES ENGINEERING SERVICE CENTER</div> <div>PORT HUENEME, CALIFORNIA 93041</div> </div> <div> <div>DUEL FUEL 1500 KW</div> <div>CONVERSION OF DIESEL POWER PLANT</div> <div>SCHEMATIC OF GAS CONVERSION SYSTEM</div> <div>SCHEMATIC OF NAVY ENGINE CONTROL UNIT</div> </div> <div> <div>SIZE</div> <div>CODE IDENT NO</div> <div>NAVJAC DRAWING NO</div> </div> <div> <div>F 80091</div> <div>CONSTR CENTER NO</div> </div> <div> <div>SCALE</div> <div>NONE</div> </div> <div> <div>SHEET</div> <div>1</div> <div>OF</div> </div>			



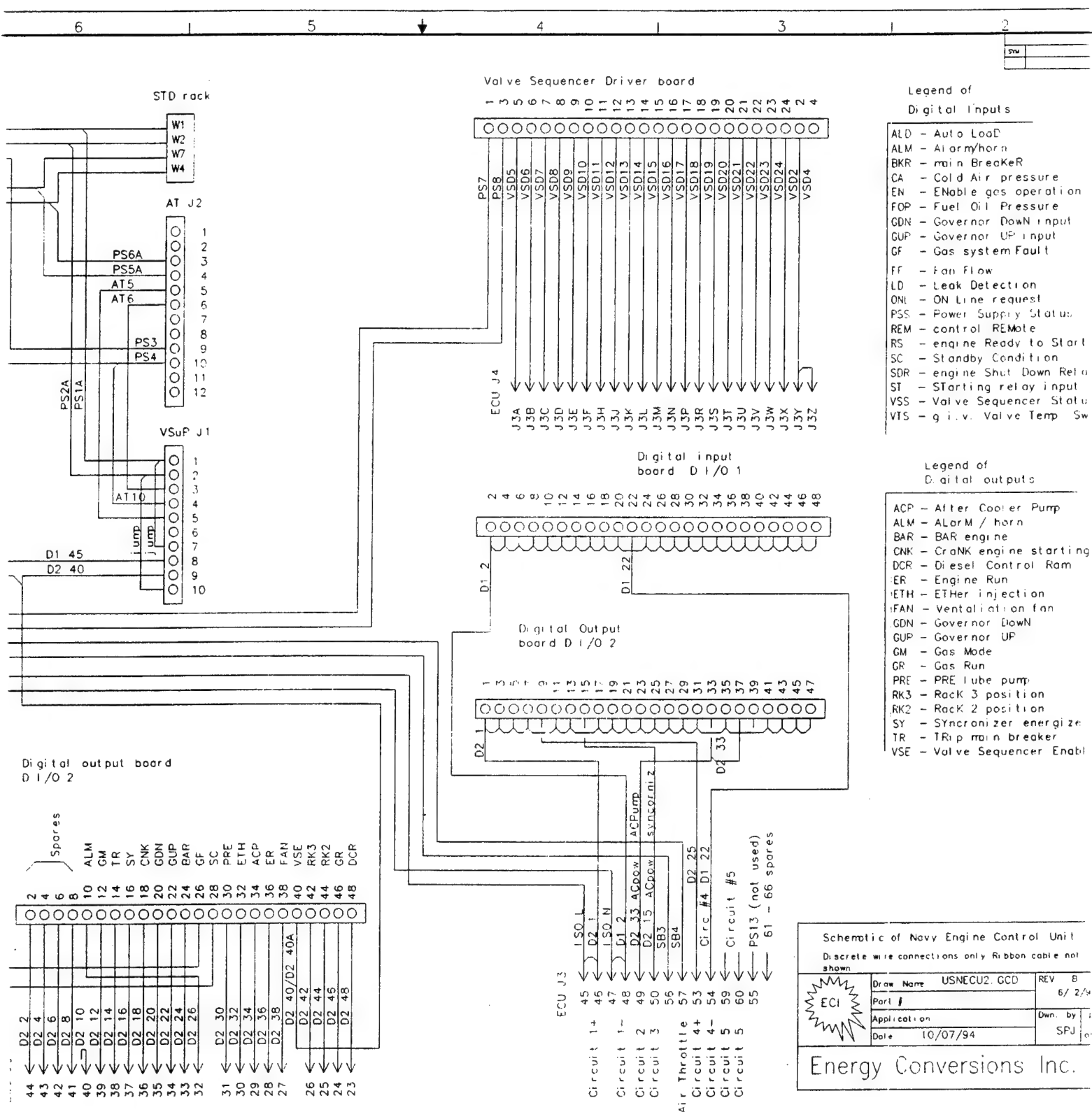
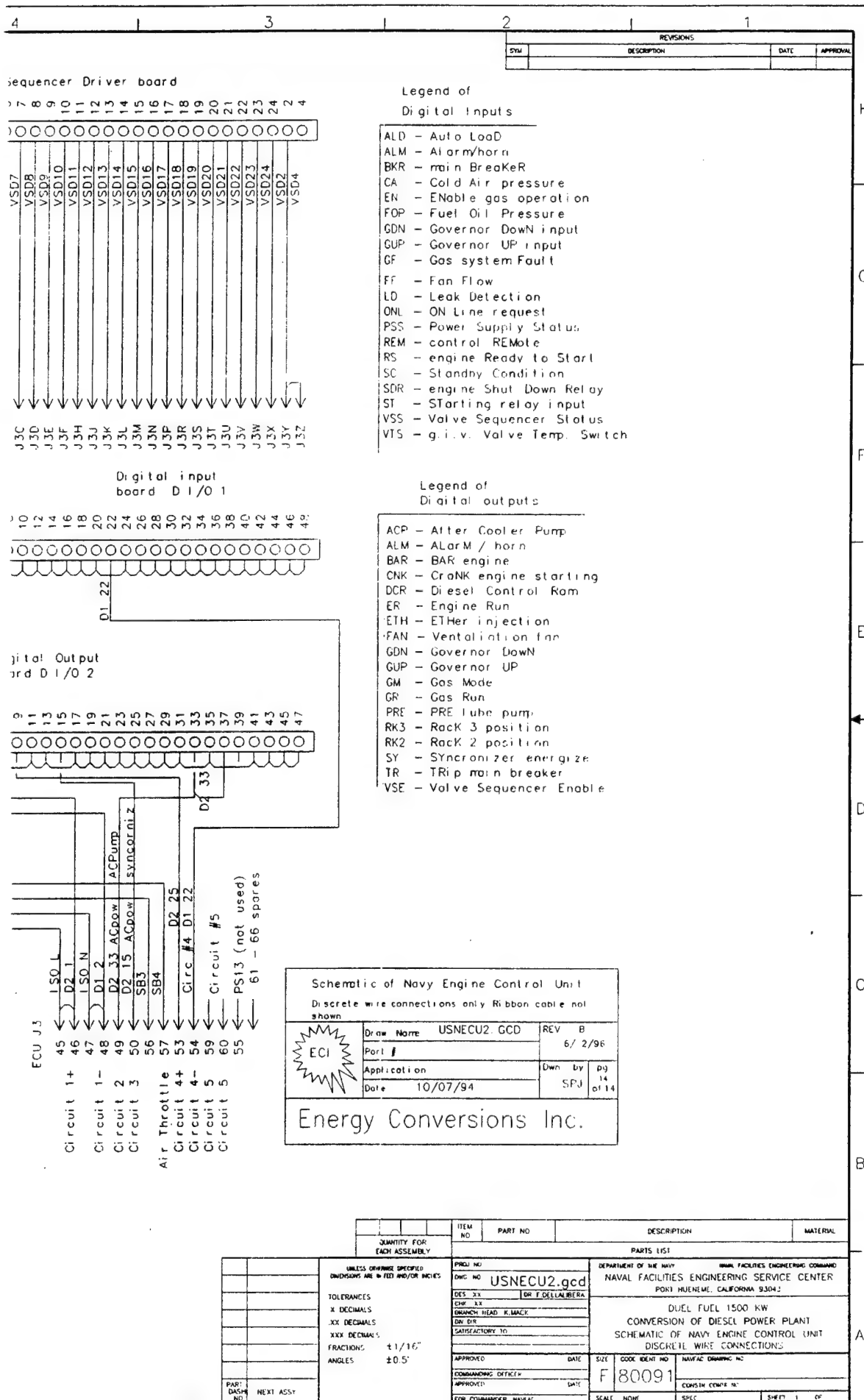


Figure 4-39. Wiring connections within ECU. 7. ASK - DO NOT SCALE

(Used by permission, Energy Conversions, Inc., U.S.A., 1996.)



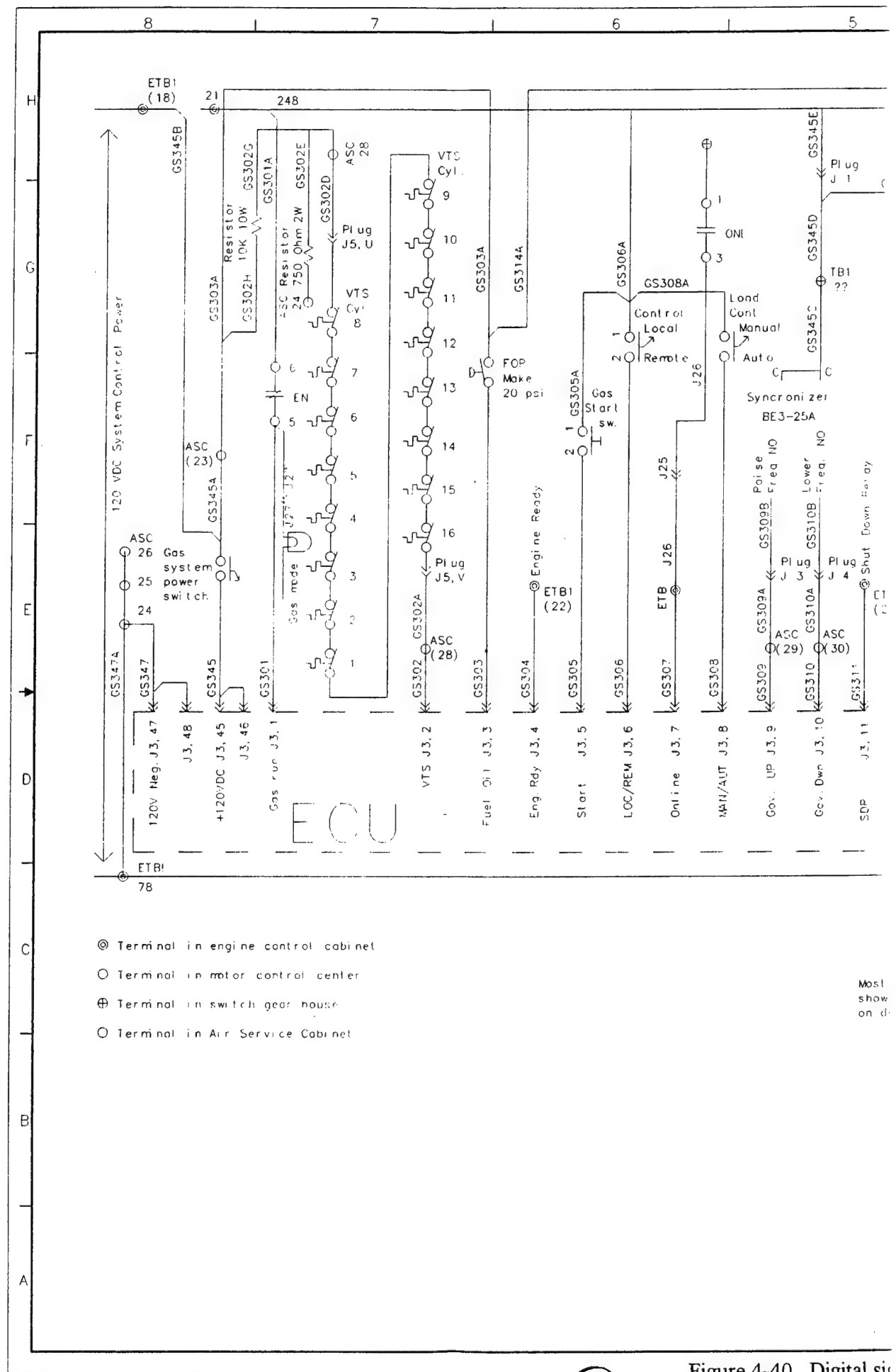
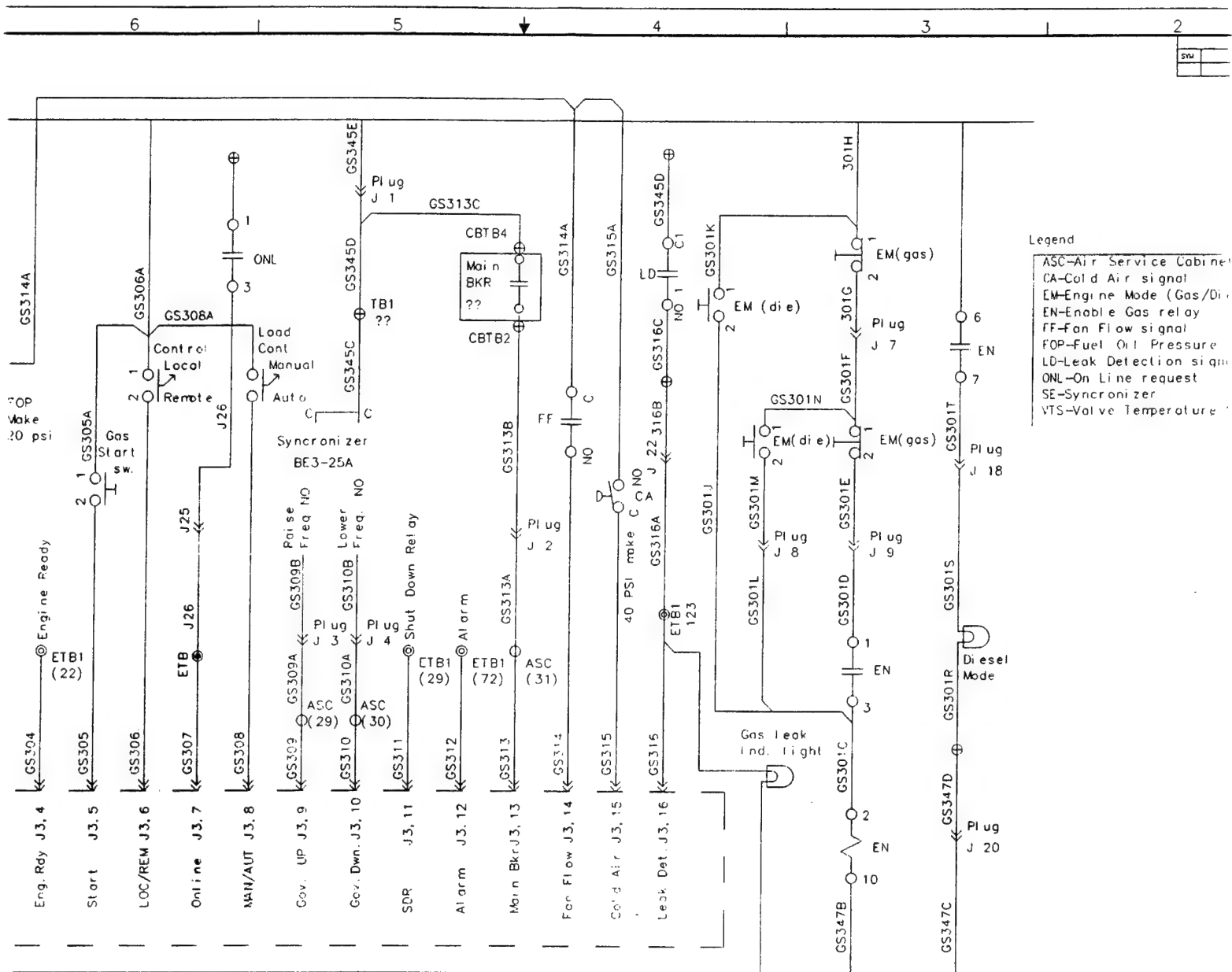
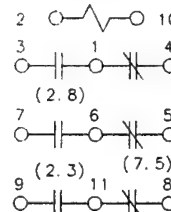


Figure 4-40. Digital signal wiring diagram.  
(Used by permission, Energy Control Systems, Inc.)





Enable Gas signal (EN)



Most ETB terminal connections shown are located on drawing #6276575

Schematic of Gas Conversion system  
ECU digital inputs

ECU	Draw. Name	USNSYS2.GCD	REV. B
	Part #		6/02/94
	Application	MP40	Own. by
	Date	10/27/94	SPJ

Energy Conversions Inc.

QUANTITY FOR EACH ASSEMBLY		ITEM NO.	PART NO.
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN FEET AND/OR INCHES		PART NO.	
TOLERANCES		Dwg. No. USNSYS2.GCD	
X DECIMALS		Dwg. Title	
XX DECIMALS		BRANCH HEAD & MARK	
XXX DECIMALS		DWG. BY	
FRACTIONS		SATISFACTORY TO	
ANGLES		APPROVED	
PART DASH NO.		COMMANDING OFFICER	
NEXT ASSY		APPROVED	
		FOR COMMANDER IN CHARGE	

Figure 4-40. Digital signal inputs to ECU.  
(Used by permission, Energy Conversions, Inc., U.S.A., 1996.)

IN DOUBT, ASK - DO NOT SCALE

2



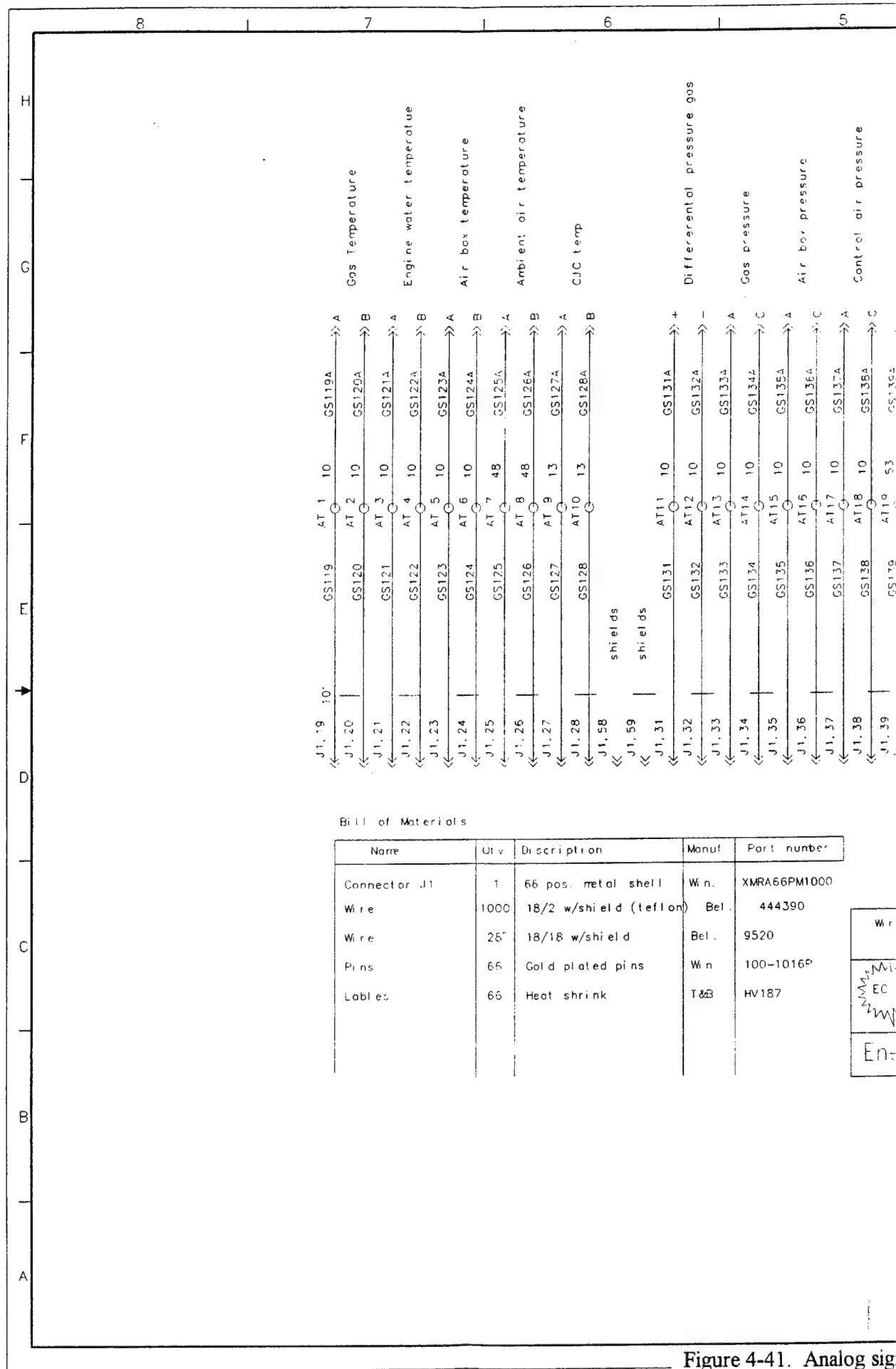
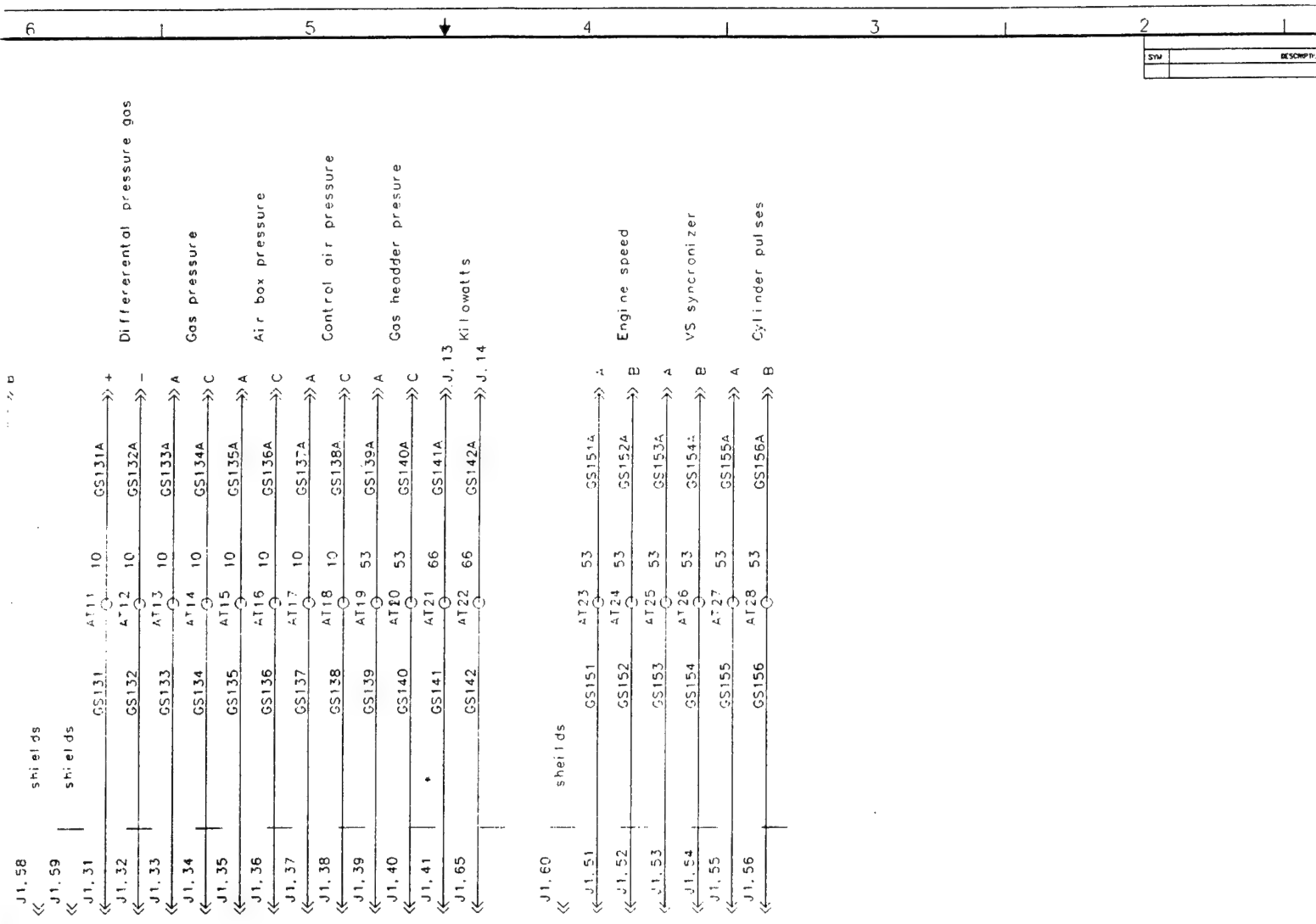


Figure 4-41. Analog sign  
(Used by permission, Energy Converter)



n	Manuf	Part number
tal shell	Win.	XMRA66PM1000
eld (teflon)	Bel.	444390
shield	Bel.	9520
ed pins	Win.	100-1016P
nk	T&B	HV187

Wire harness and connections for ECU analog group

	Draw. Name	USNSYS8. g.c.d	REV	A
	Part #		11/22/90	
	Application		Drawn by	pg 14
	Date	10/27/94	SPJ	

Energy Conversions Inc.

ITEM NO.	PART NO.	DEL.
QUANTITY FOR EACH ASSEMBLY		
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN FEET AND/OR INCHES TOLERANCES: X DECIMALS XX DECIMALS XXX DECIMALS FRACTIONS: $\pm 1/16"$ ANGLES: $\pm 0.5^\circ$		
DRAWING NO. ECI-DF-4 DES. BY: JIM F. DELLALIBERA CHG. BY: BRANCH HEAD: K. MACK DIV. DIS: SAFETY FACTORY TO: WIRE, CABLES: NORMAN HELGASON DEC 1990 APPROVED: DATE: SIZE: COORDINATOR: F. 800 COMMANDING OFFICER: DATE: SCALE: NONE FOR COMMANDER, NAVAL:		
PART DASH NO.	NEXT ASSY	

Figure 4-41. Analog signal inputs to ECU. (Used by permission, Energy Conversions, Inc., U.S.A., 1996.)

2

3			2			1		
REVISES								
SYM		DESCRIPTION				DATE		

H  
G  
F  
E  
D  
C  
B  
A

Engine speed

VS synchronizer

Cylinder pulses

J1.52 → GS152 53 GS1524 B  
 J1.53 → GS153 53 GS153A A  
 J1.54 → GS154 53 GS154A B  
 J1.55 → GS155 53 GS155A A  
 J1.56 → GS156 53 GS156A B

ECU

REV. A  
11/22/96

OWN BY SPJ PG 8 of 14

inc.

UNLESS OTHERWISE SPECIFIED  
DIMENSIONS ARE IN FEET AND/OR INCHES

TOLERANCES:  
 X DECIMALS  
 .XX DECIMALS  
 .XXX DECIMALS  
 FRACTIONS: ± 1/16"  
 ANGLES: ± 0.5°

PART DESIGN NO. NEXT ASSY

ITEM NO. PART NO. DESCRIPTION MATERIAL

PARTS LIST

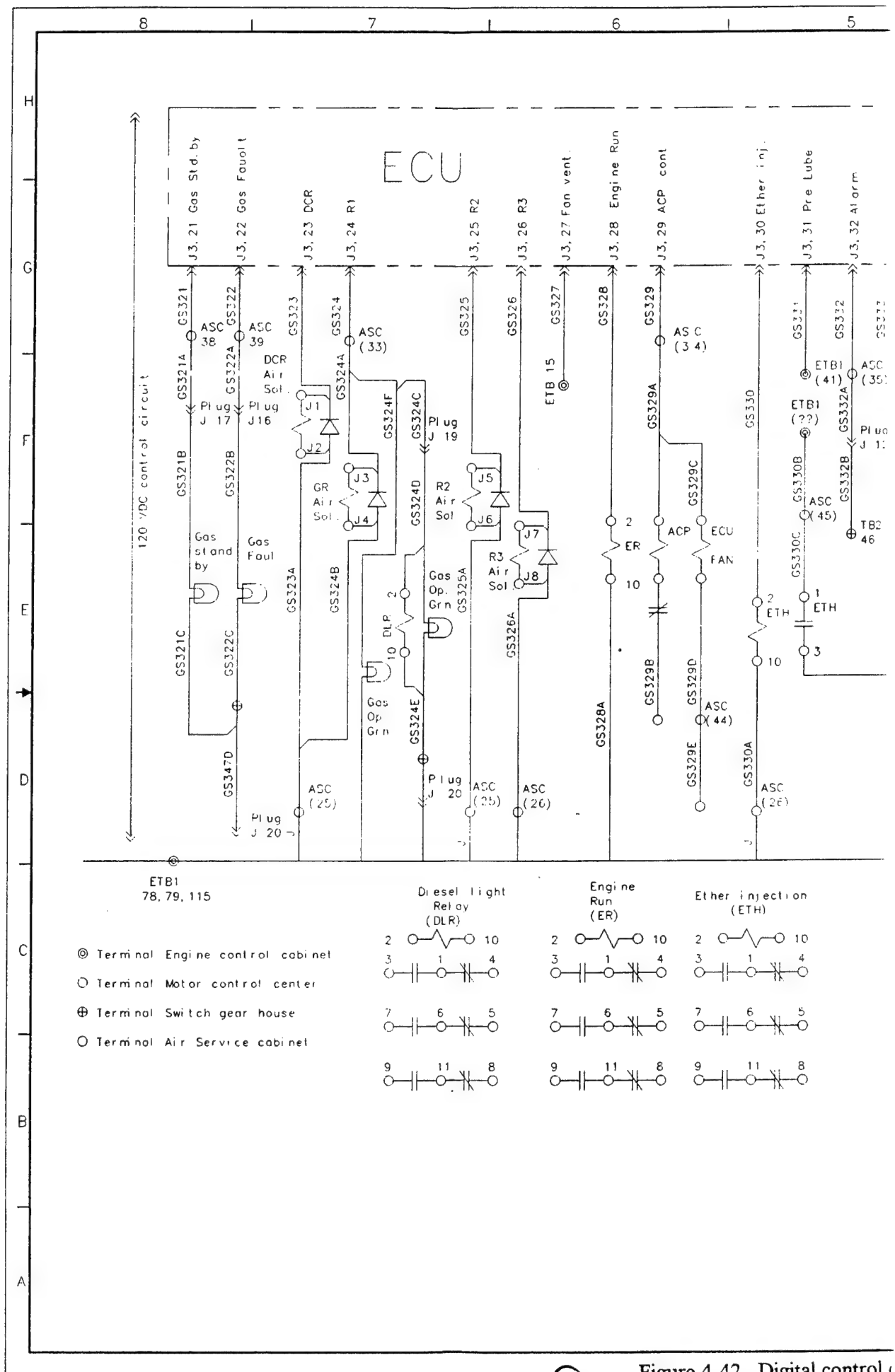
PROJ NO  
 DWG NO **ECI-DF-4**  
 DES XX  
 CWS XX  
 SEARCH HEAD X NAME  
 DW DR  
 SATISFACTORY TO  
 MIKE CHILDER  
 NORMAN MITCHELL DET 1506  
 APPROVED DATE  
 COMMANDING OFFICER  
 APPROVED DATE  
 FOR COMMANDER, INITIAL

DEPARTMENT OF THE NAVY  
 NAVAL FACILITIES ENGINEERING SERVICE CENTER  
 PORT HUENEME, CALIFORNIA 93043  
 DUEL FUEL 1500 KW  
 CONVERSION OF DIESEL POWER PLANT  
 SCHEMATIC OF GAS CONVERSION SYSTEM  
 WIRE HARNESS AND CONNECTIONS FOR ECU  
 ANALOG GROUP

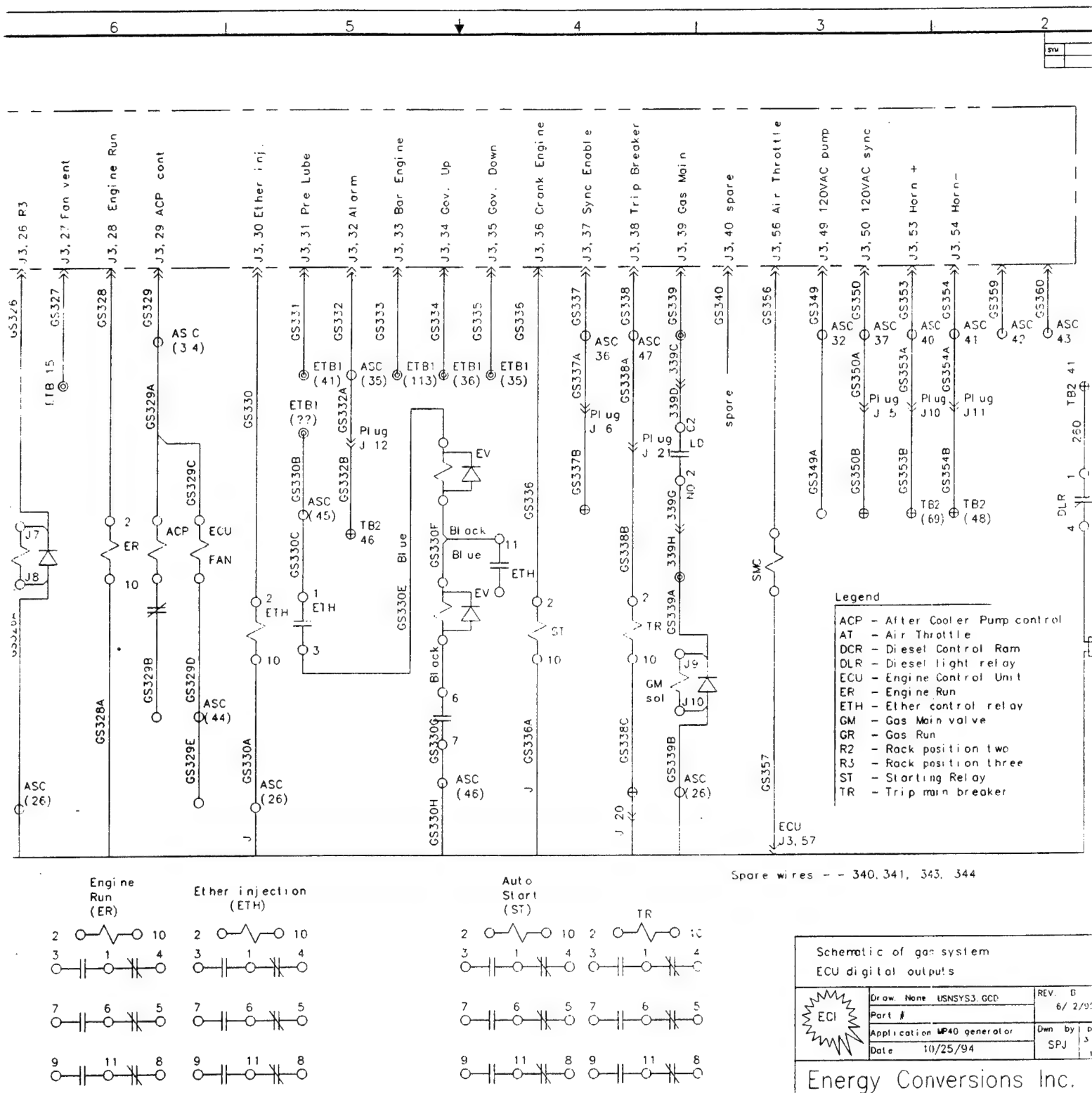
SIZE CODE IDENT NO  
**F 80091**  
 NAME AC DRAWING NO  
 COMPTON CENTER NO  
 SCALE NONE SPEC SHEET 1 OF

JB1. ASK - DO NOT SCALE

3







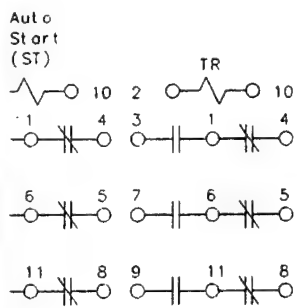
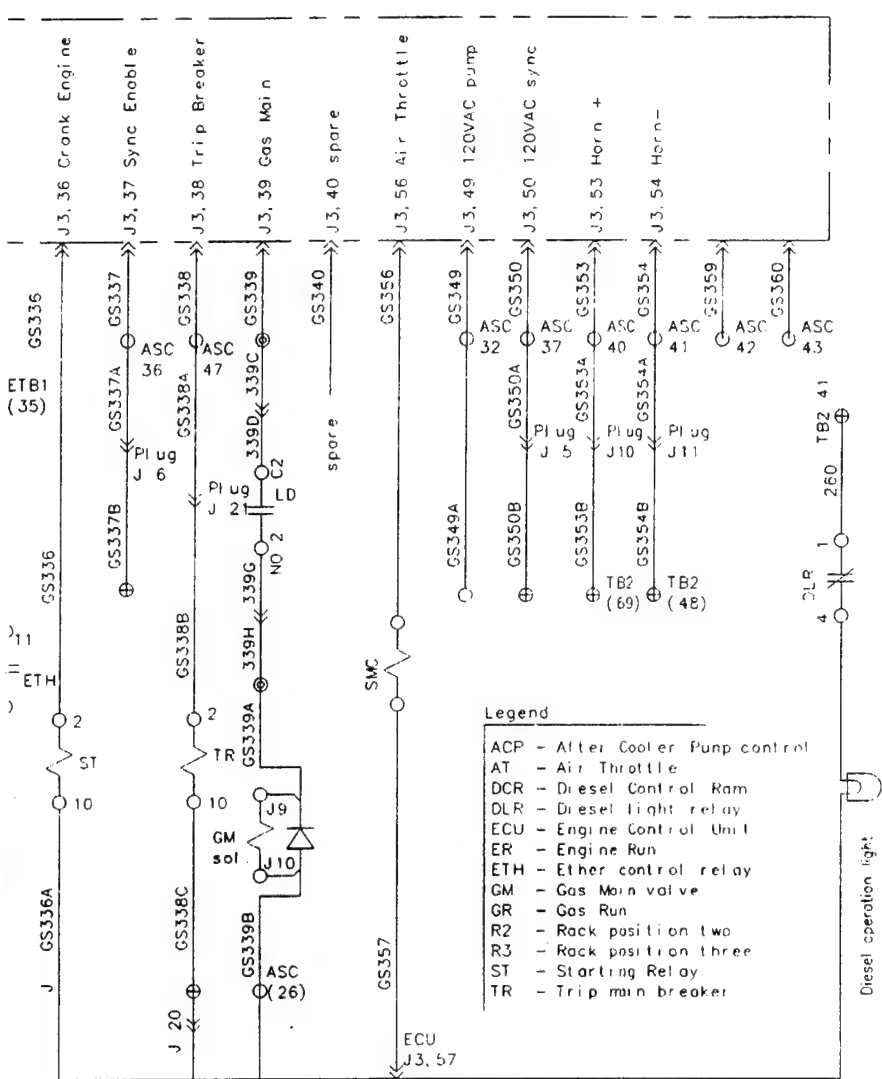
Schematic of gas system			
ECU digital outputs			
	Draw. Name	USNSYS3.GCD	REV. B
	Part #		6/2/95
	Application	MP40 generator	Drawn by
	Date	10/25/94	SPJ
Energy Conversions Inc.			

QUANTITY FOR EACH ASSEMBLY		ITEM NO.	PART NO.
UNLESS OTHERWISE SPECIFIED		DWC NO. USNSYS3.4	
DIMENSIONS ARE IN FEET AND/OR INCHES		DWC NO. 01. F.D.E. 4	
TOLERANCES:		DWC NO. 01. F.D.E. 4	
X DECIMALS		DWC NO. 01. F.D.E. 4	
XX DECIMALS		DWC NO. 01. F.D.E. 4	
XXX DECIMALS		DWC NO. 01. F.D.E. 4	
FRACTIONS: ±1/16"		DWC NO. 01. F.D.E. 4	
ANGLES: ±0.5°		DWC NO. 01. F.D.E. 4	
PART NO.		DWC NO. 01. F.D.E. 4	
NEXT ASSY		DWC NO. 01. F.D.E. 4	
APPROVED:		DWC NO. 01. F.D.E. 4	
APPROVED:		DWC NO. 01. F.D.E. 4	
FOR COMMANDER, USNS		DWC NO. 01. F.D.E. 4	

Figure 4-42. Digital control outputs from ECU.  
 (Used by permission, Energy Conversions, Inc., U.S.A., 1996.)

N DOUBT, ASK - DO NOT SCALE

2



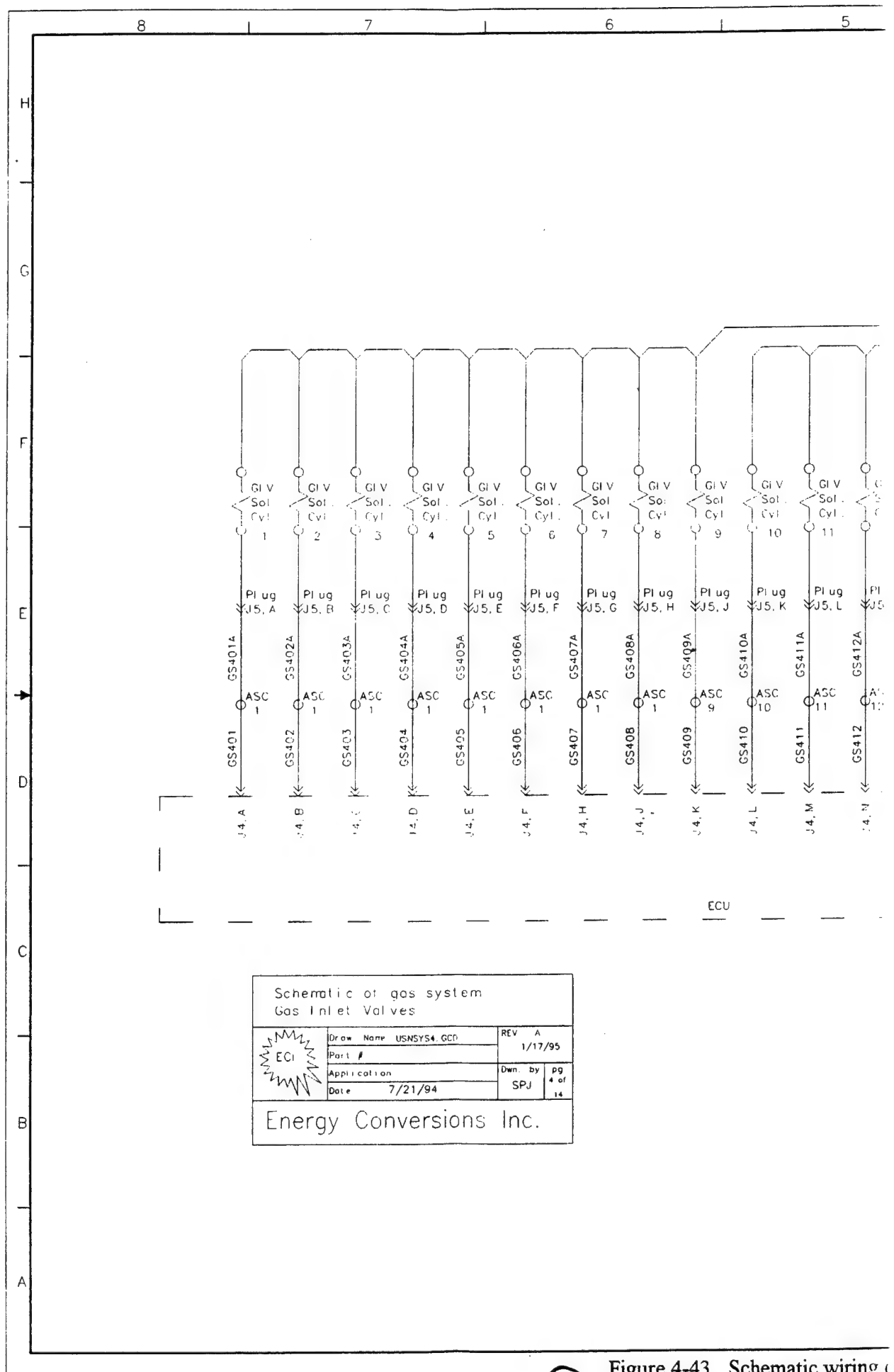
Spore wires - - 340, 341, 343, 344

Schematic of gas system  
ECU digital outputs

Draw. Name	USNSYS3 GCE	REV	B
Part #			
Application	MP40 generator	Own by	pg 3 of 14
Date	10/25/94	SPJ	

Energy Conversions Inc.

QUANTITY FOR EACH ASSEMBLY		ITEM NO.	PART NO.	DESCRIPTION	MATERIAL
		PARTS LIST			
		<div style="display: flex; justify-content: space-between;"> <div> <p>UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN FEET AND/OR INCHES</p> <p>TOLERANCES X DECIMALS XX DECIMALS XXX DECIMALS FRACTIONS ±1/16" ANGLES ±0.5°</p> </div> <div> <p>PROJ. NO. DWG. NO. <b>USNSYS3.gcd</b> DES. BY CHK. BY BRANCH HEAD, K. MACK DW. OR SATISFACTORY TO APPROVED DATE COMMANDING OFFICER APPROVED DATE FOR COMMANDER, NAVAL</p> </div> <div> <p>DEPARTMENT OF THE NAVY NAVAL FACILITIES ENGINEERING SERVICE CENTER PORT HUENEME, CALIFORNIA 93041</p> <p style="text-align: center;">DUEL FUEL 1500 KW CONVERSION OF DIESEL POWER PLANT SCHEMATIC OF GAS CONVERSION SYSTEM ECU DIGITAL OUTPUTS</p> <p>NAVFAC DRAWING NO. <b>F 80091</b> CONSTR. CONTR. NO. SCALE: NONE SHEET 1 OF</p> </div> </div>			
PART DASH NO.	NEXT ASSY				



Schematic of gas system  
Gas Inlet Valves



Draw Name	USNSYS4.GCD	REV	A
Part #			1/17/95
Application		Drawn by	SPJ
Date	7/21/94	pg	4 of 14

Energy Conversions Inc.



Figure 4-43. Schematic wiring (Used by permission, Energy Con.)

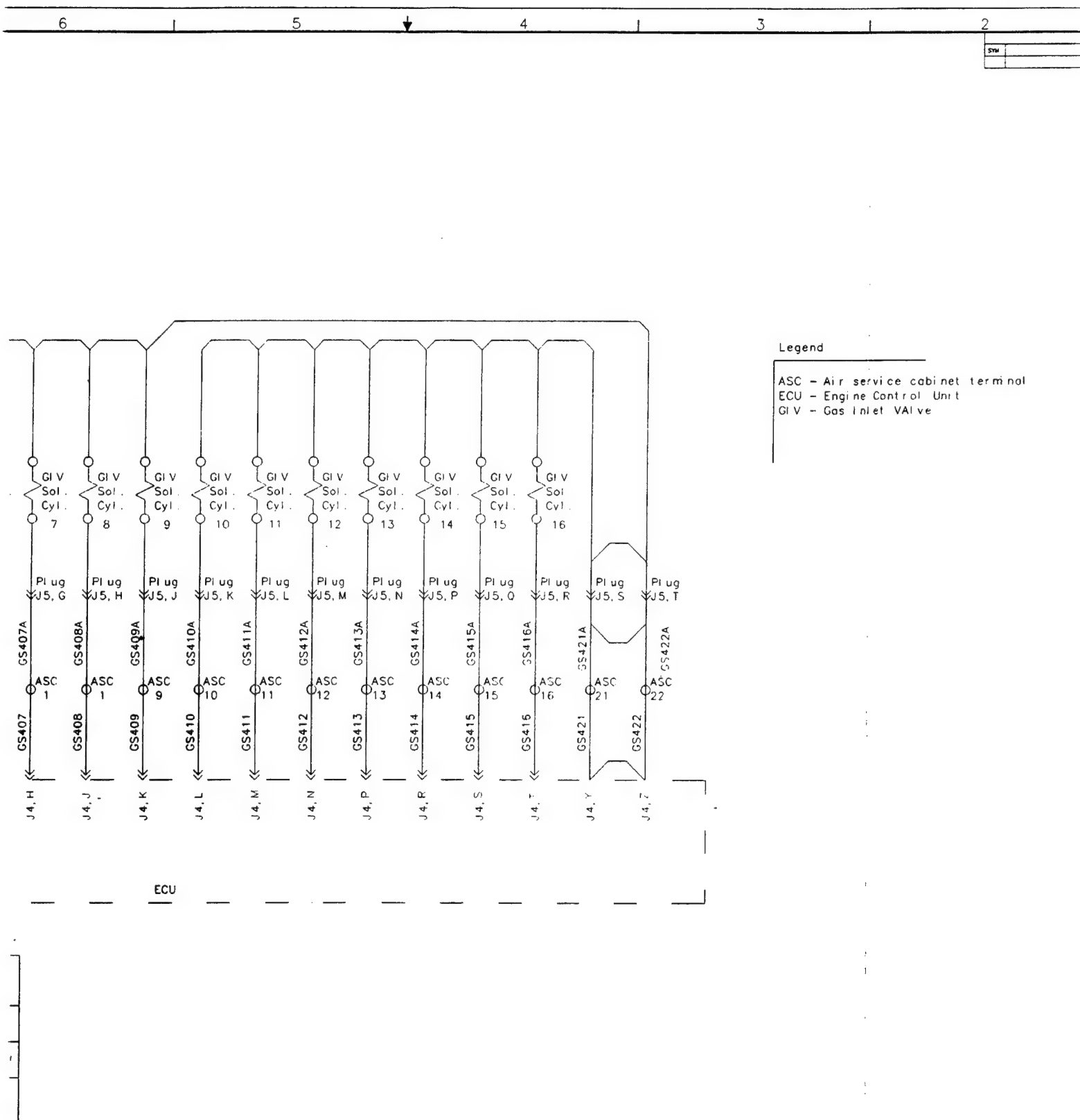


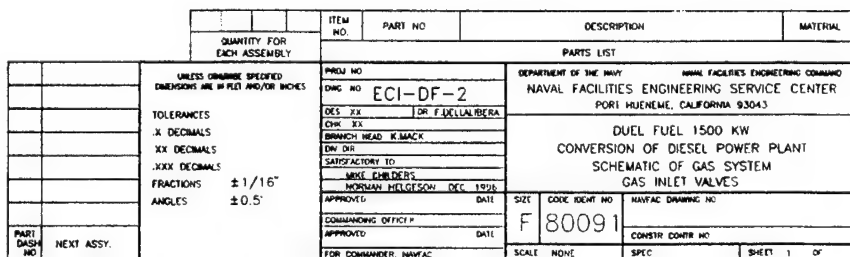
Figure 4-43. Schematic wiring diagram for control of GIV's.

(Used by permission, Energy Conversions, Inc., U.S.A., 1996.)

DO NOT SCALE

QUANTITY FOR EACH ASSEMBLY		ITEM NO.	PART NO.
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN FEET AND/OR INCHES		ECL-DF-2	
TOLERANCES:		DRAWN BY: K. MACK	
.X DECIMALS		CHECKED BY: K. MACK	
.XX DECIMALS		SATISFACTORY TO:	
.XXX DECIMALS		W. K. CHILDERS	
FRACTIONS $\pm 1/16"$		NORMAN HILGEMAN DEC 1996	
ANGLES $\pm 0.5^\circ$		APPROVED: _____	
PART BASH NO.	NEXT ASSY:	COMMANDING OFFICER #	DATE
		APPROVED: _____	DATE
		FOR COMMANDER: HAWAII	SCALE

2



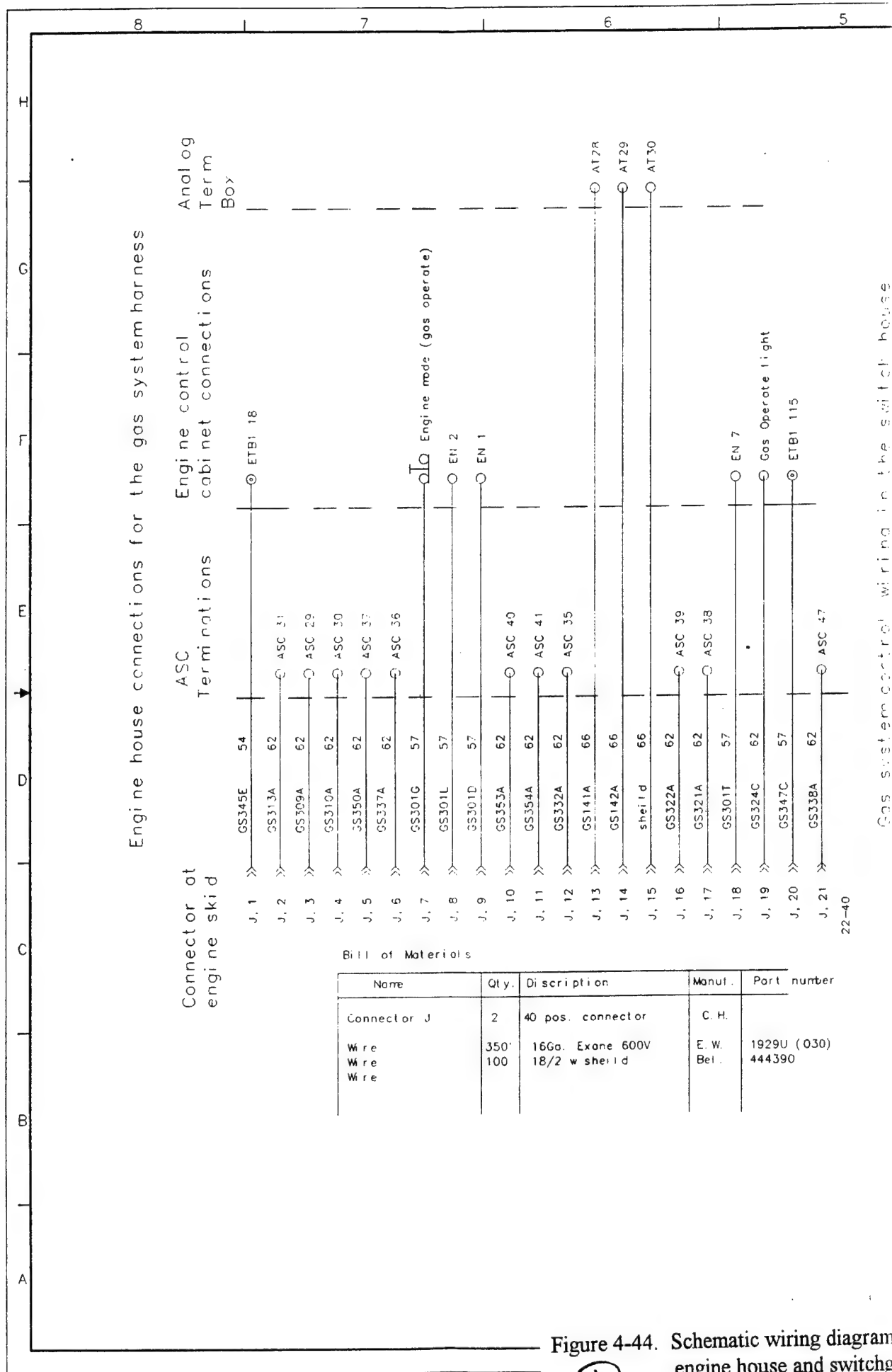
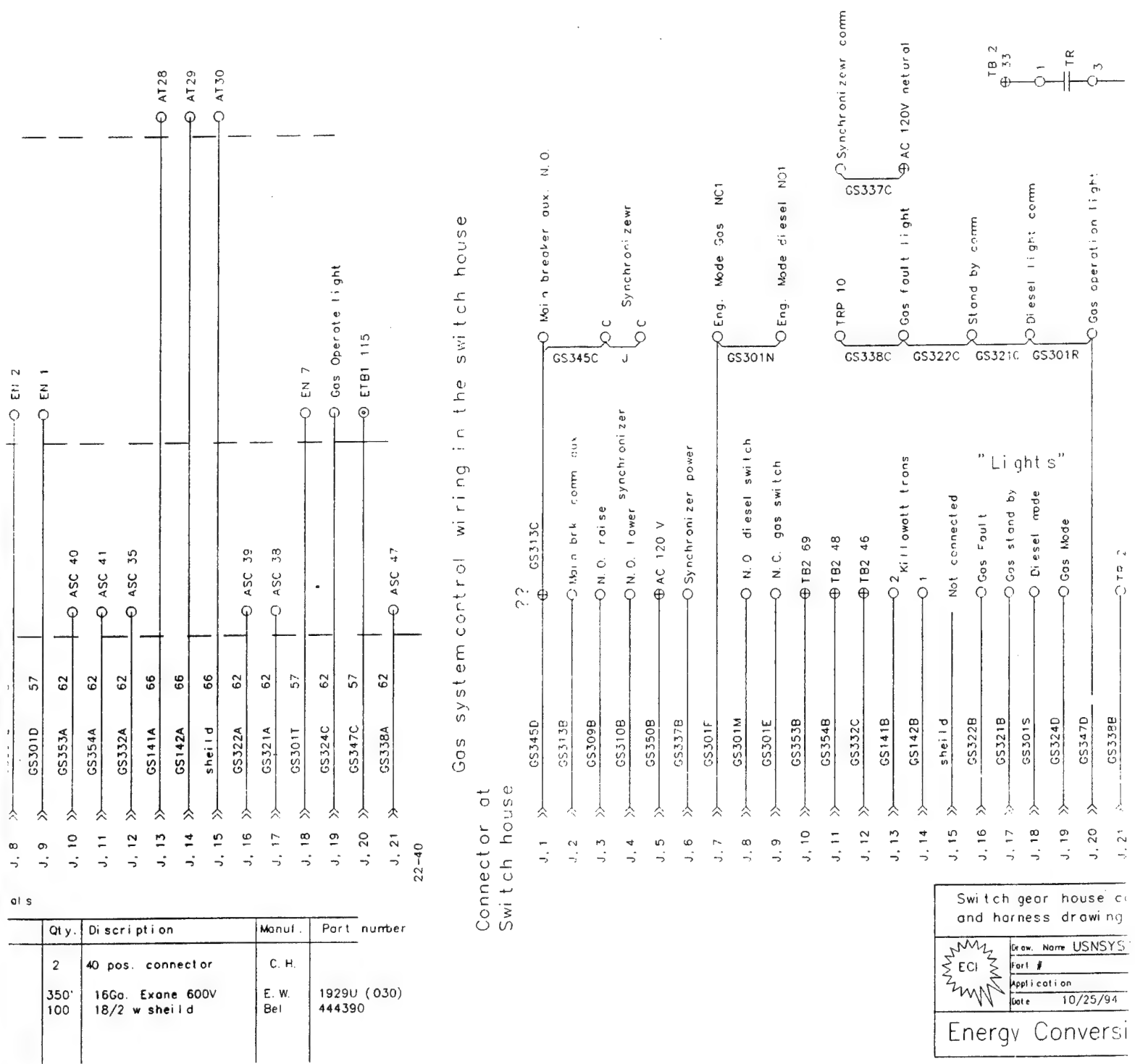


Figure 4-44. Schematic wiring diagram engine house and switch house  
(Used by permission, Energy Co.)



Qty.	Description	Manuf.	Part number
2	40 pos. connector	C. H.	
350' 100	16Ga. Exane 600V 18/2 w shield	E. W. Bel	1929U (030) 444390

Switch gear house and harness drawing

ECI

Draw. Name USNSYS

Part #

Application

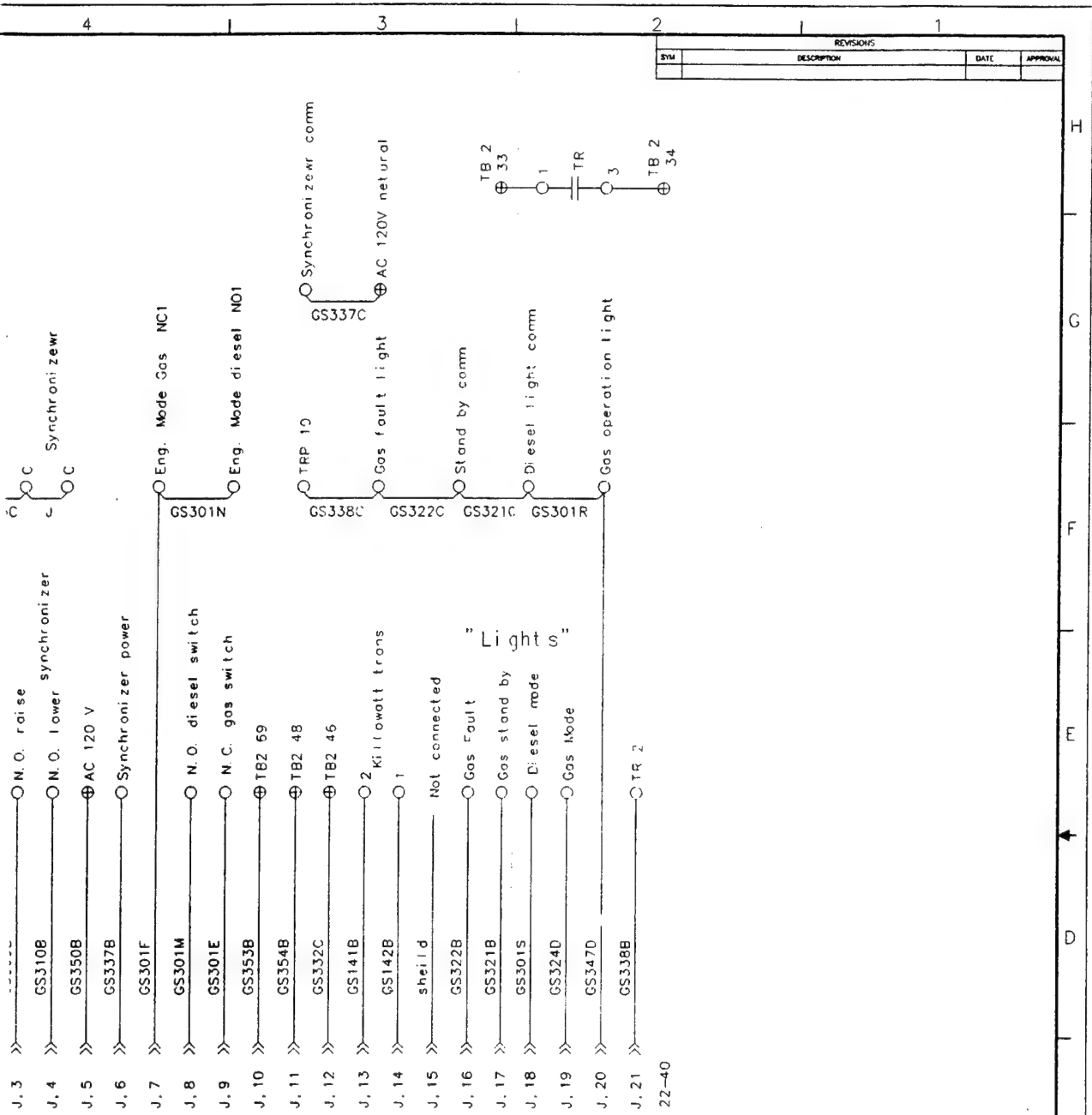
Date 10/25/94

Energy Conversion

QUANTITY FOR EACH ASSEMBLY		ITEM NO.
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN FEET AND/OR INCHES		PROJ. NO.
TOLERANCES		DWG. NO. U
X DECIMALS		DES. BY
XX DECIMALS		COR. BY
XXX DECIMALS		BRANCH RELAY
FRACTIONS ±1/16"		DIV. DIR.
ANGLES ±0.5°		SATISFACTORY
PART DASH NO.	NEXT ASSY	APPROVED
		APPROVED
		FOR COMPANY

Figure 4-44. Schematic wiring diagram showing electrical connection points in engine house and switchgear through connecting umbilical harness.  
(Used by permission, Energy Conversions, Inc., U.S.A., 1996.)





Switch gear house connection and harness drawing

ECI

Draw. Name: USNSYS11.GCD REV A 1/17/95

Part #

Application

Date: 10/25/94

Dwn. by: SPJ pg. 11 of 14

Energy Conversions Inc.

QUANTITY FOR EACH ASSEMBLY		ITEM NO.	PART NO.	DESCRIPTION	MATERIAL
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN FEET AND/OR INCHES		PARTS LIST			
TOLERANCES: X DECIMALS XX DECIMALS XXX DECIMALS FRACTIONS: $\pm 1/16"$ ANGLES: $\pm 0.5^\circ$		PROJ NO: USNSYS11.gcd Dwg NO: USNSYS11.gcd DES: 22 CHK: 21 BRANCH HEAD: S. MACA DWG OR: SATISFACTORY TO: APPROVED: DATE: F 80091 COMMANDING OFFICER: DATE: APPROVED: DATE: FOR COMMANDER, NAVFAC			
PART DASH NO.		NEXT ASSY		DEPARTMENT OF THE NAVY NAVAL FACILITIES ENGINEERING SERVICE CENTER PORT HUENEME, CALIFORNIA 93043 DUEL FUEL 1500 KW CONVERSION OF DIESEL POWER PLANT SCHEMATIC OF GAS CONVERSION SYSTEM SWITCH GEAR HOUSE CONNECTION AND HARNESS DRAWING NAVFAC DRAWING NO: DONSTR CENTER NO: SCALE: NONE SPEC: SHEET 1 OF	

rical connection points in  
nnecting umbilical harness.  
1, 1996.)

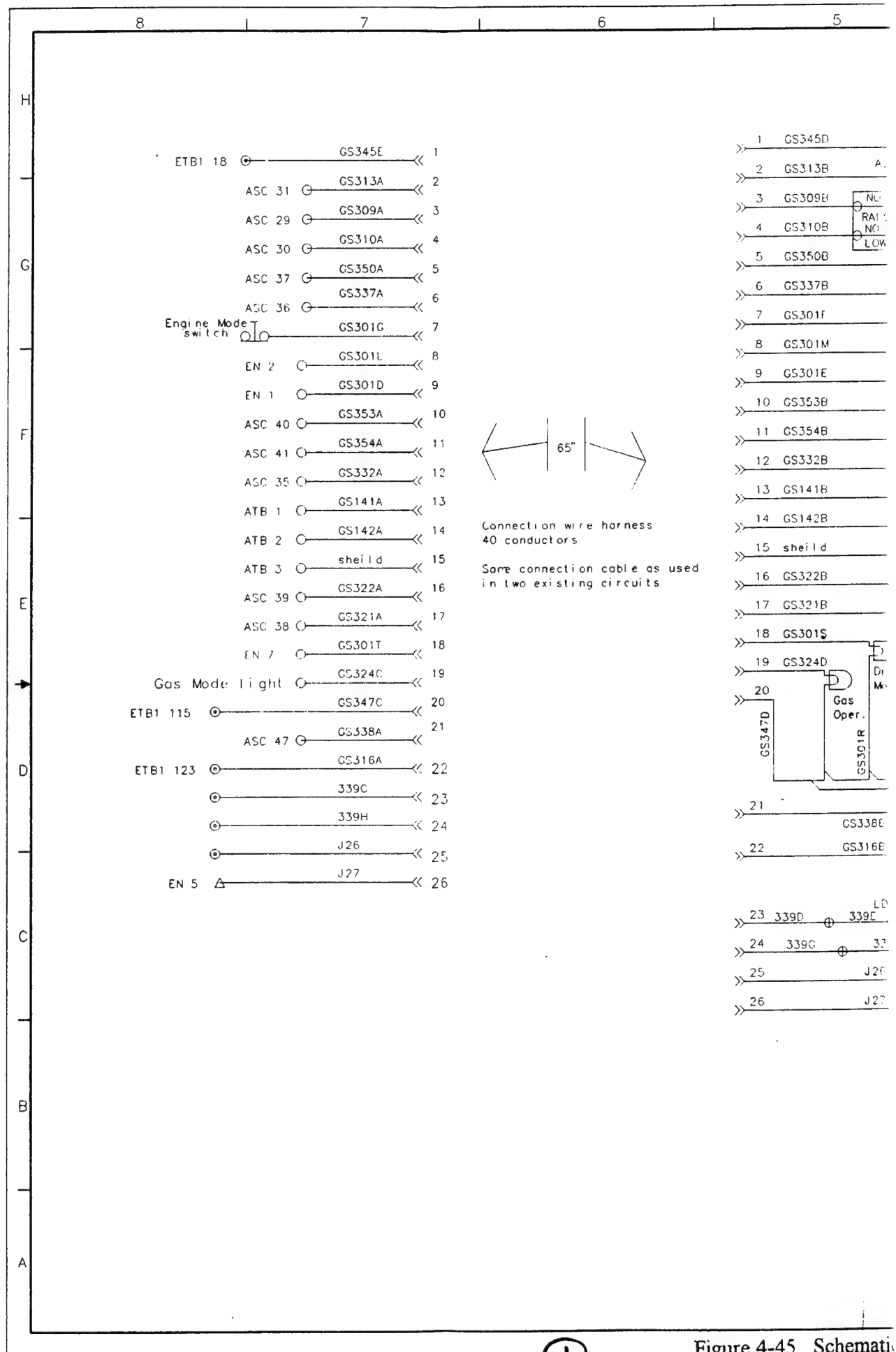


Figure 4-45. Schematic  
(Used by permission, Ener)

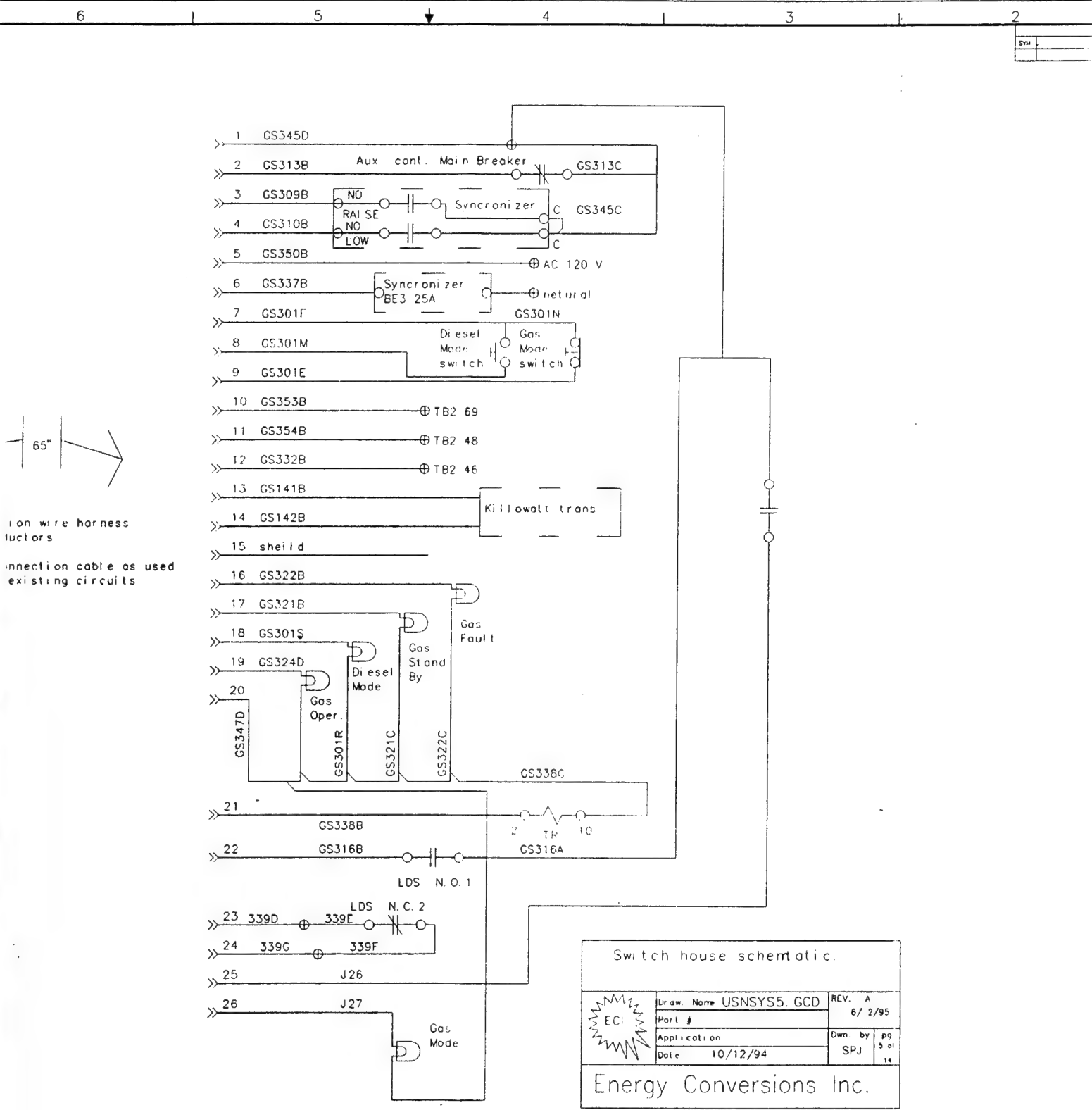


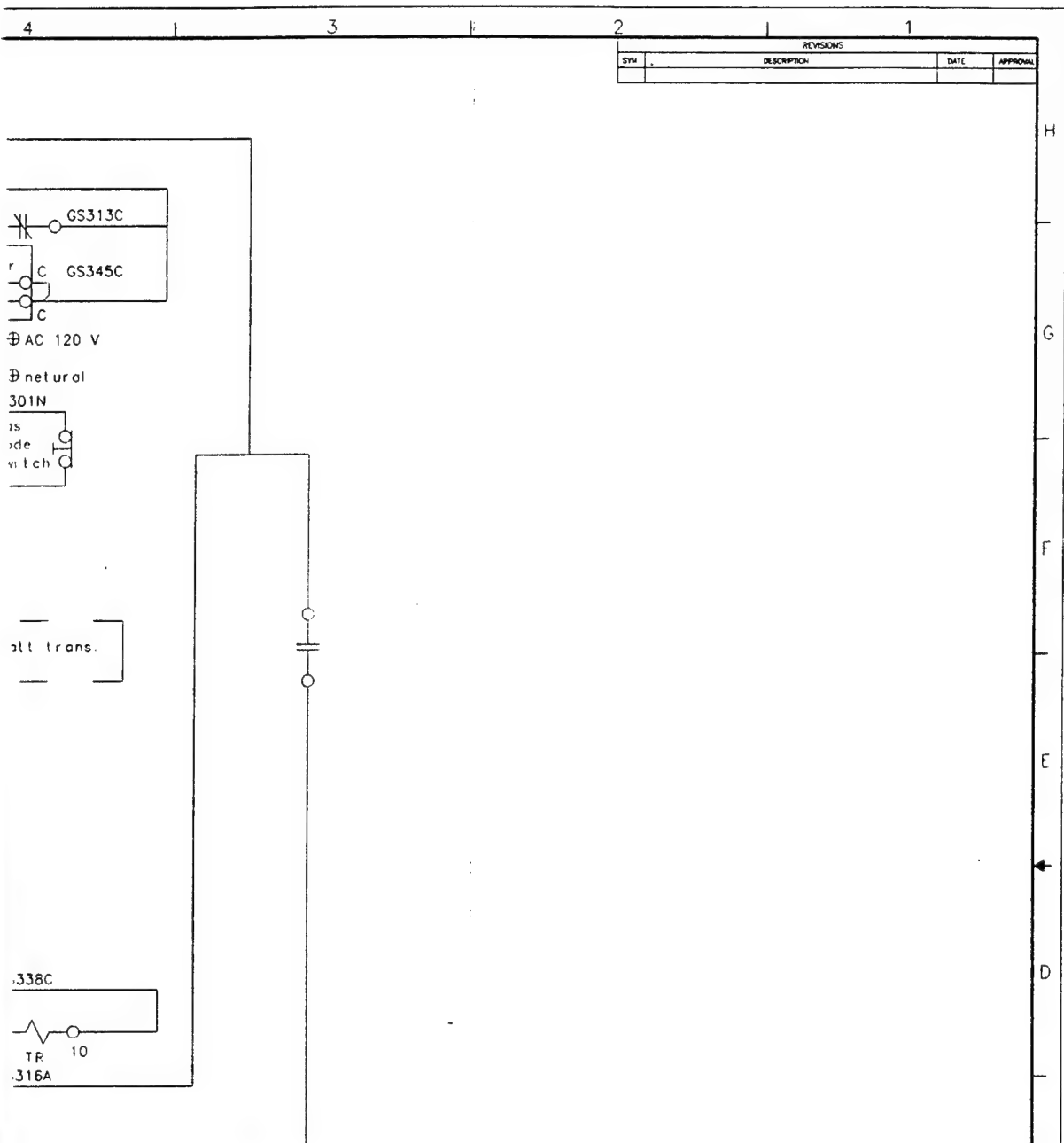
Figure 4-45. Schematic wiring detail for switchgear.  
(Used by permission, Energy Conversions, Inc., U.S.A., 1996.)

DO NOT SCALE

2

ITEM NO.		PART NO.	
QUANTITY FOR EACH ASSEMBLY			
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN FEET AND/OR INCHES			
TOLERANCES			
X DECIMALS			
XX DECIMALS			
XXX DECIMALS			
FRACTIONS $\pm 1/16"$			
ANGLES $\pm 0.5^\circ$			
PART	QTY	DATE	DATE
DISCH	NO	NO	NO
NEXT ASSY		FOR COMMANDER SURVIV	

PROJ NO	USNSYS5.gcd
DWG NO	DR T. DELLALBERA
CHK BY	
BRANCH HEAD	K. MALL
DRY DR	
SATISFACTORY TO	
APPROVED	DATE
COMMANDING OFFICER	DATE
APPROVED	DATE



Switch house schematic.

ECI	Draw. Name	USNSYS5. GCD	REV. A
	Part #		6/ 2/95
	Application		Own by pg
	Date	10/12/94	SPJ 3 of 14

Energy Conversions Inc.

QUANTITY FOR EACH ASSEMBLY		ITEM NO.	PART NO.	DESCRIPTION	MATERIAL
		PARTS LIST			
		PROJ NO Dwg NO <b>USNSYS5.gcd</b> DES. XX CHK. XX BRANCH HEAD K.MAC TRV DR SATISFACTORY TO APPROVED DATE COMMANDING OFFICER APPROVED DATE FOR COMMANDER, NAVFAC			
		DEPARTMENT OF THE NAVY NAVAL FACILITIES ENGINEERING SERVICE CENTER PORT HUENEME, CALIFORNIA 93043 DUEL FUEL 1500 KW CONVERSION OF DIESEL POWER PLANT SCHEMATIC OF GAS CONVERSION SYSTEM SWITCH HOUSE SCHEMATIC SIZE CODE IDENT NO <b>F 80091</b> NAVFAC DRAWING NO CONSTR CONTR NO SCALE INCHES SPEC SHEET 1 OF			

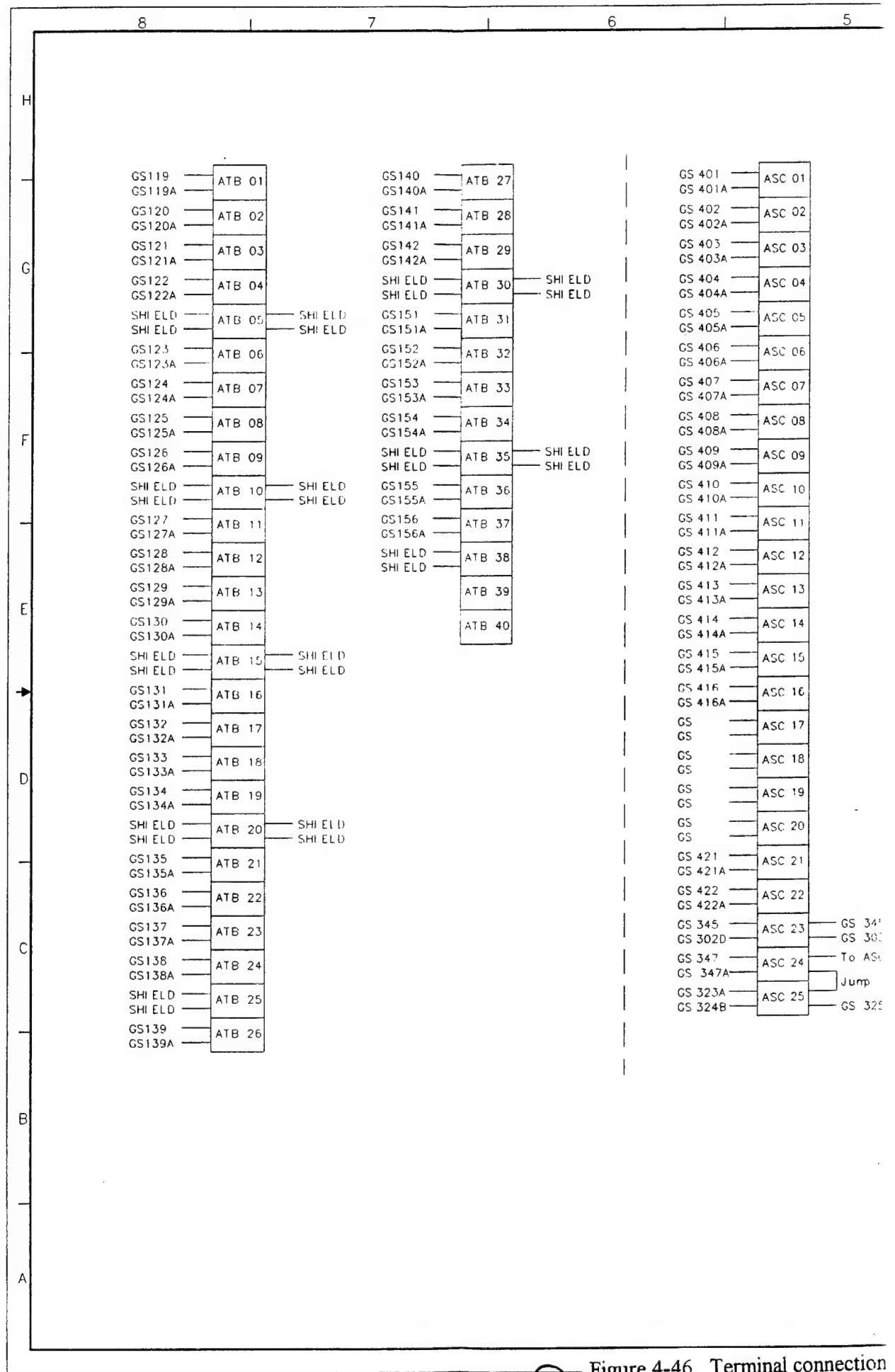


Figure 4-46. Terminal connection  
(Used by permission, Ener.)

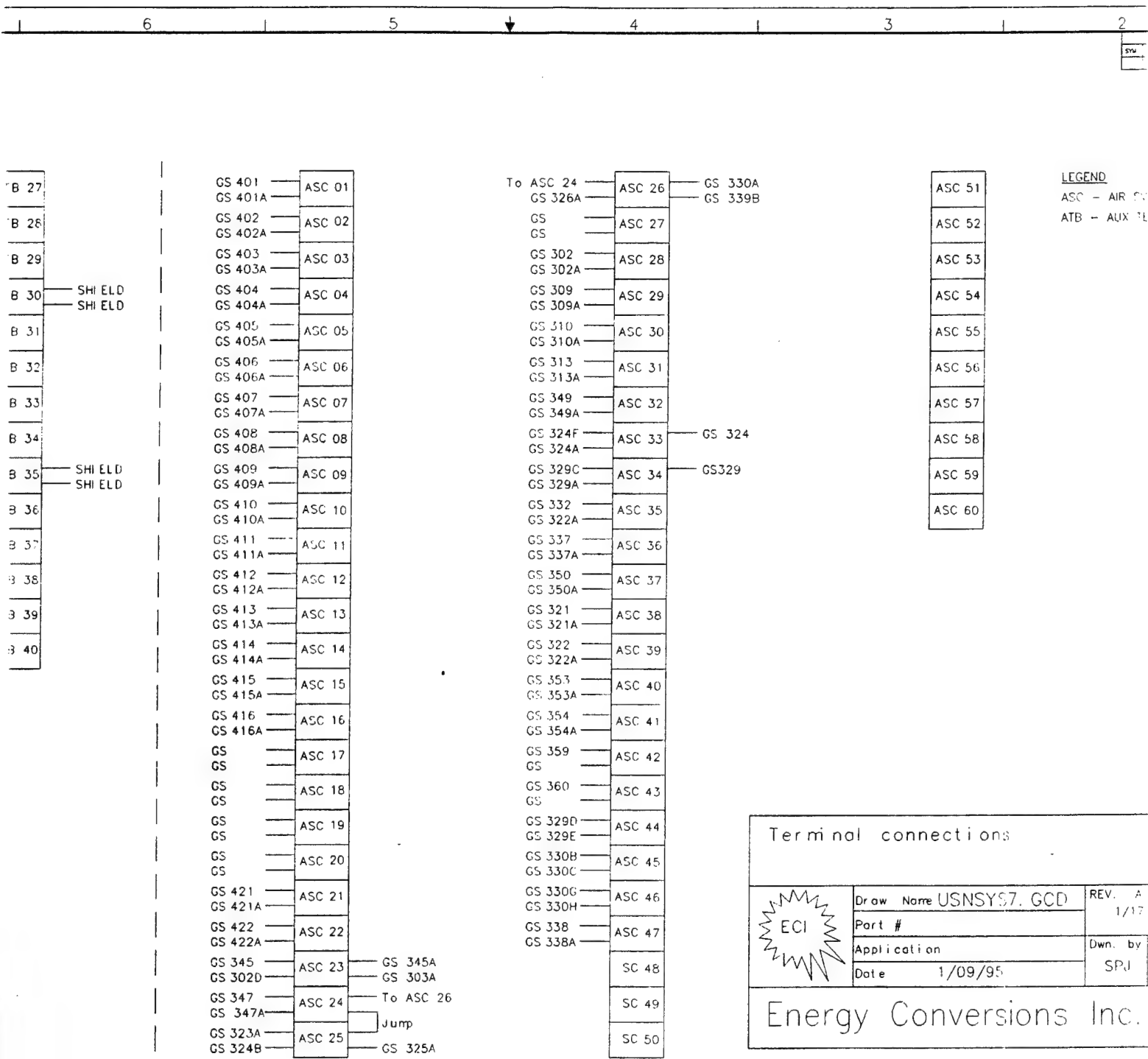
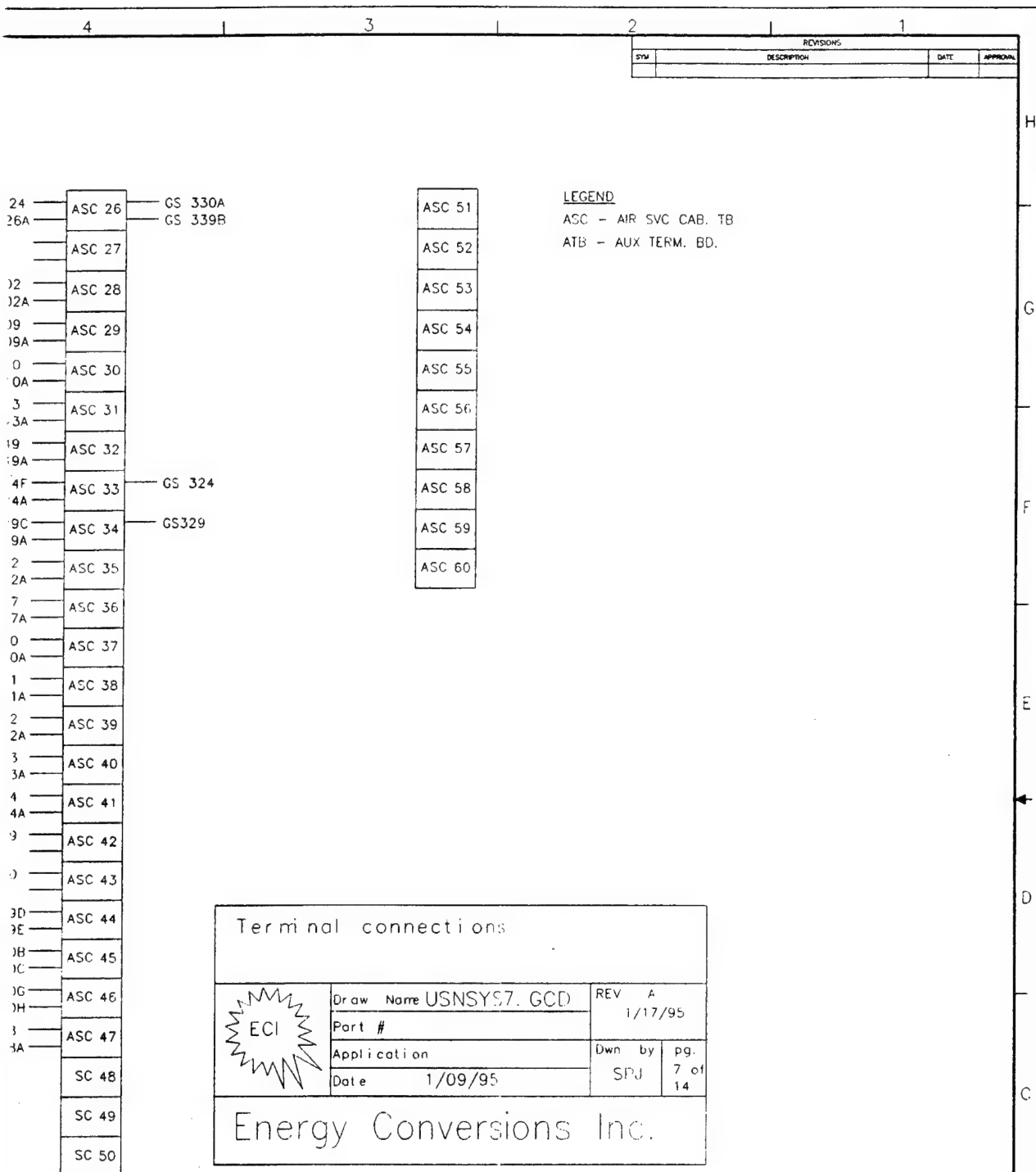
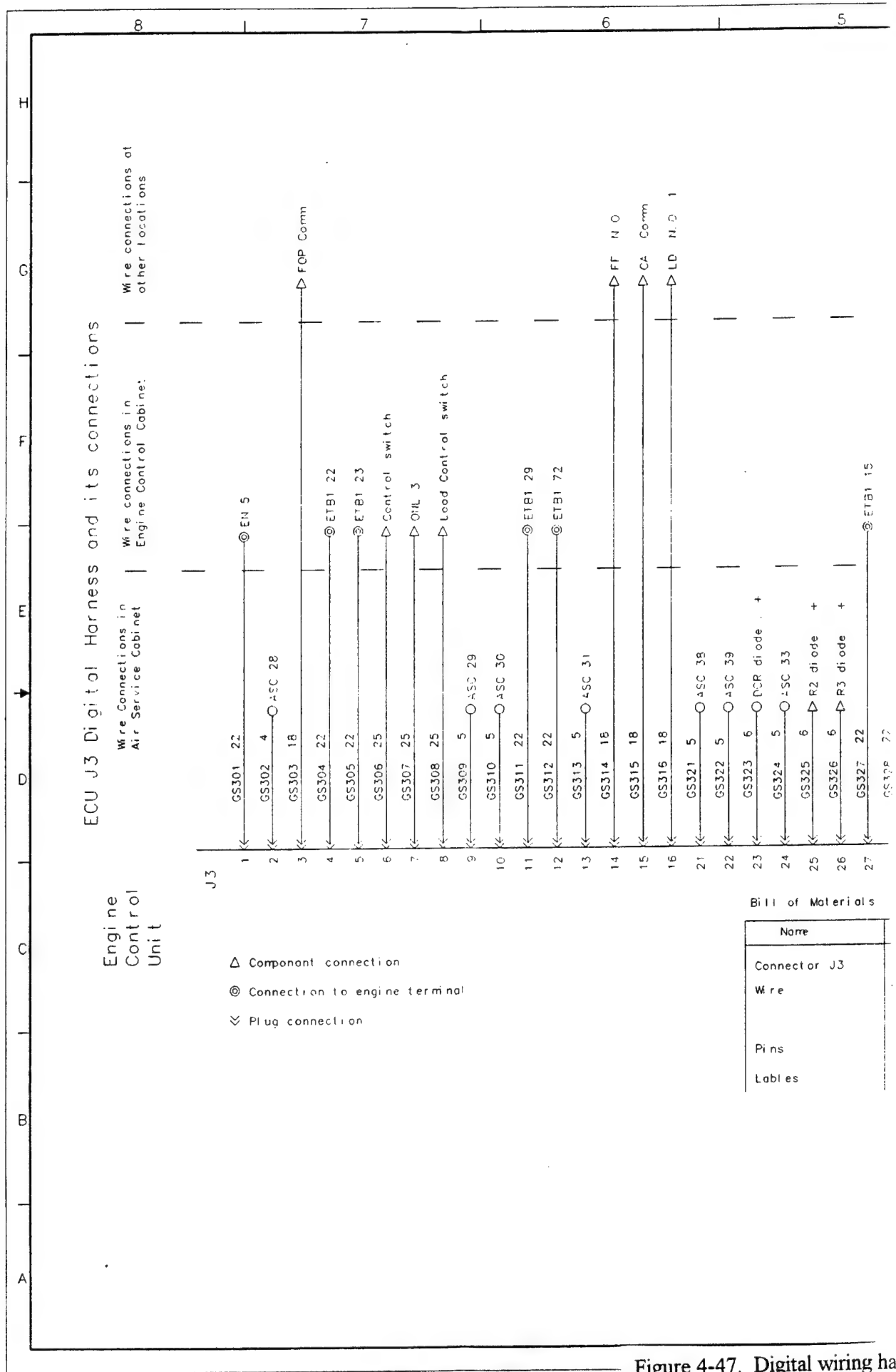


Figure 4-46. Terminal connections with ASC and analog termination box.  
 (Used by permission, Energy Conversions, Inc., U.S.A., 1996.)

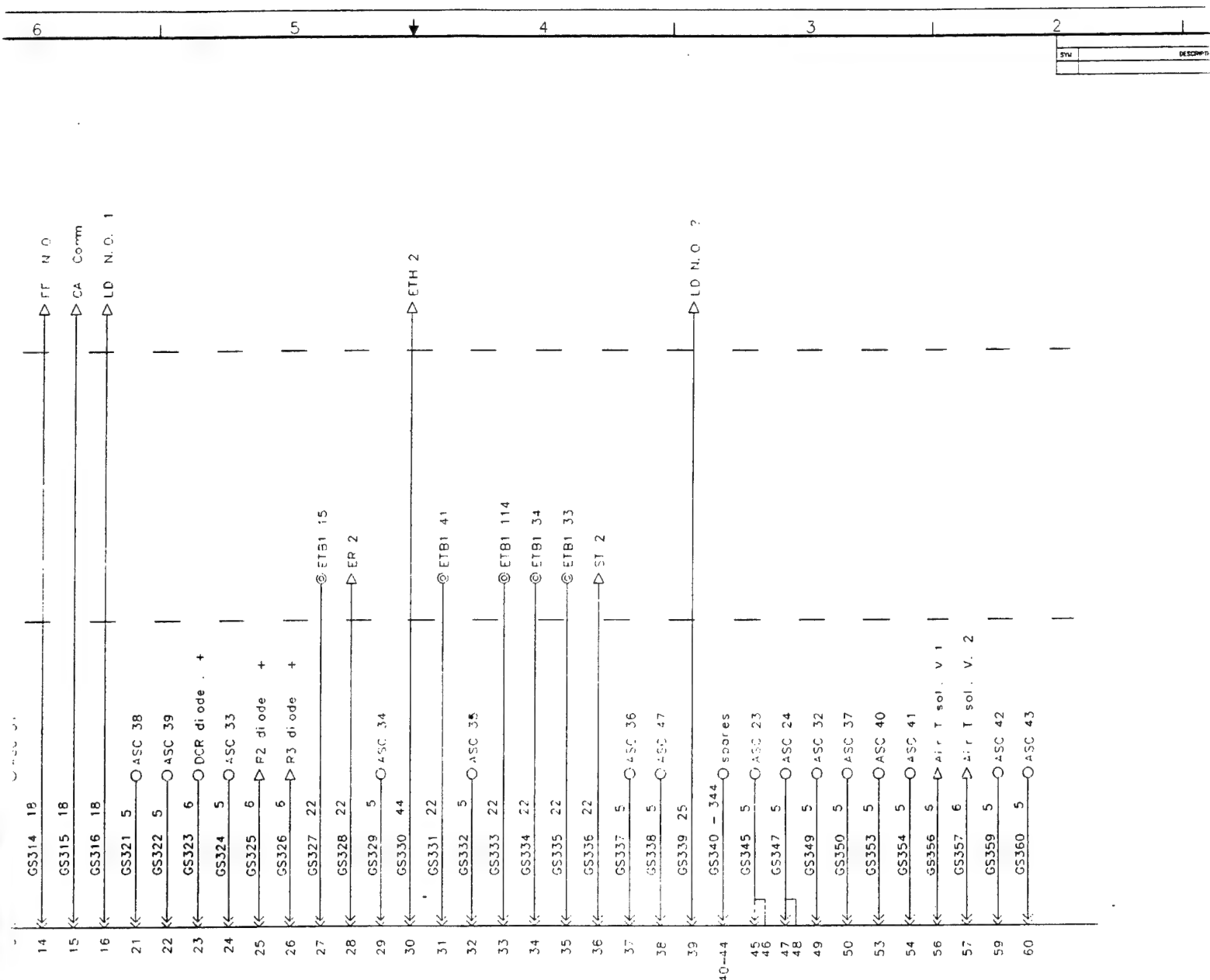


QUANTITY FOR EACH ASSEMBLY		ITEM NO	PART NO	DESCRIPTION	MATERIAL
		PARTS LIST			
<small>UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES AND/OR DECIMALS</small>  TOLERANCES: X DECIMALS XX DECIMALS XXX DECIMALS FRACTIONS $\pm 1/16"$ ANGLES $\pm 0.5^\circ$		PROJ NO <b>ECI-DF-3</b>		DEPARTMENT OF THE NAVY NAVAL FACILITIES ENGINEERING SERVICE CENTER PORT HUENEME, CALIFORNIA 93041	
		DES XX CHK XX HUSCHHEAD R MACK DW DW SATISFACTORY TO MARK CHILDERS NORMAN HILGSON DEC 1995		DUEL FUEL 1500 KW CONVERSION OF DIESEL POWER PLANT SCHEMATIC OF GAS CONVERSION SYSTEM TERMINAL CONNECTIONS	
		APPROVED DATE COMMANDING OFFICER APPROVED DATE FOR COMMANDER, NAVFAC		SIZE CODE IDENT NO <b>F 80091</b> NAVFAC DRAWING NO CONSTR CONTR NO	
		SCALE IN/OUT SPC		SHEET 1 OF	





**Figure 4-47. Digital wiring ha**  
(Used by permission, Energy Con



Bill of Materials

Name	Qty.	Description	Manuf.	Part number
Connector J3	1	66 pos. metal shell	Win	XMRA66PM-1000
Wire	1000	16/1 Exane 1000v	EW	1929U (030)
Pins	66	Gold plated pins	Win	100-1016P
Labels	66	Heat shrink	T&D	HVM187-9-1S

Gas conversion digital harness drawing and connections

Draw. Name: USNSYS9.GCD REV. B 4/27/95

Part #

Application

Date: 10/07/94

Urn by: SPJ pg. 9 of 14

Energy Conversions Inc.

QUANTITY FOR EACH ASSEMBLY

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN FEET AND/OR INCHES

TOLERANCES

.X DECIMALS

.XX DECIMALS

.XXX DECIMALS

FRACTIONS:  $\pm 1/16"$

ANGLES:  $\pm 0.5^\circ$

PROJ. NO. USNSYS9.gcd

DES. 311 OR 7 DECIMALS

BRANCH HEAD: N.M.C.P.

DN IN

SATISFACTORY TO

APPROVED

DATE

COMMANDED OFFICER

DATE

FOR COMMANDER, NAVY

DEPARTMENT OF THE NAVAL FAC.

CONVE I SCHEM GAS CONVE

SIZE CODE 8000

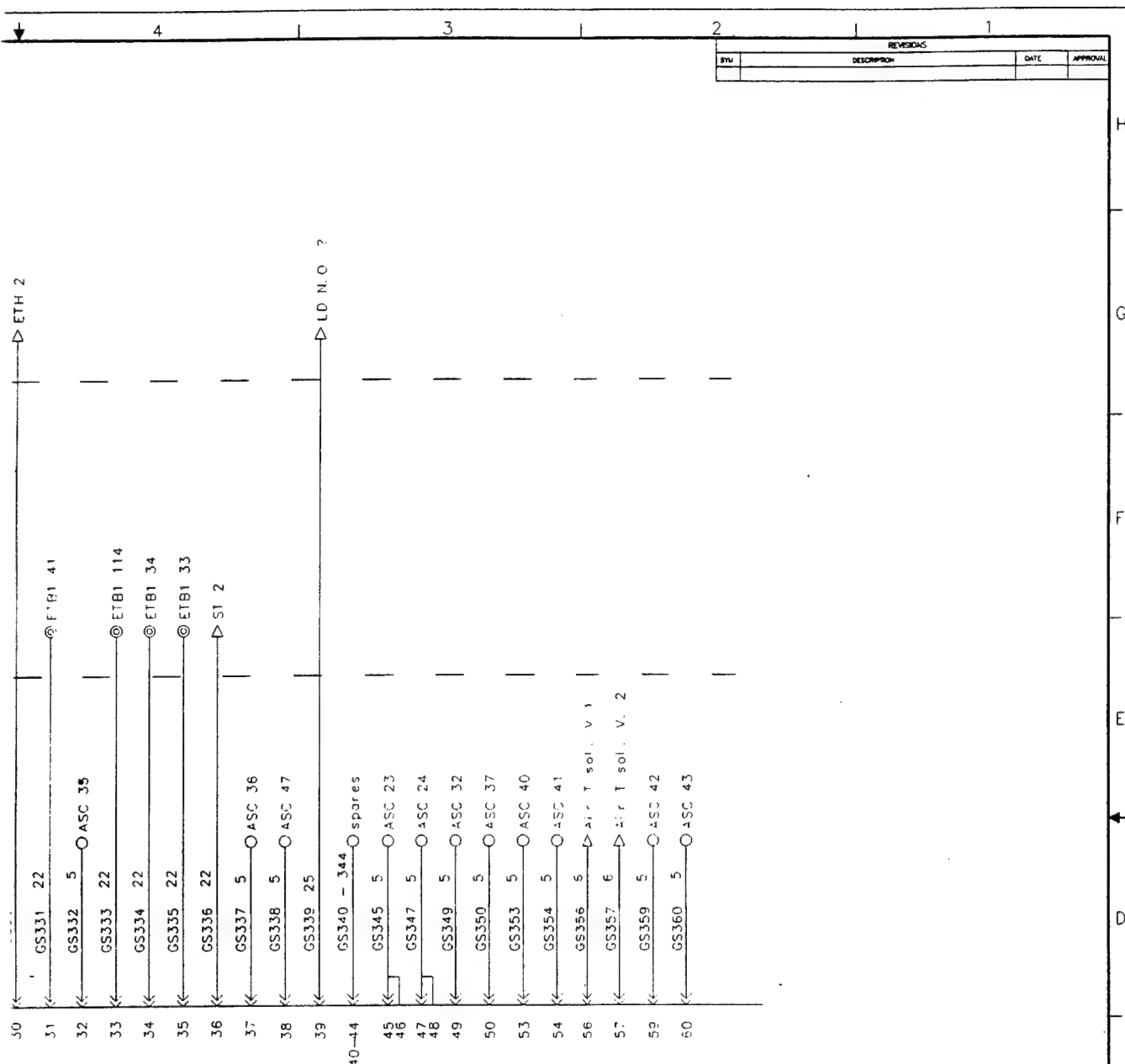
SCALE: NONE

Figure 4-47. Digital wiring harness connections to ECU.


SK - DO NOT SCALE

(Used by permission, Energy Conversions, Inc., U.S.A., 1996.)

2

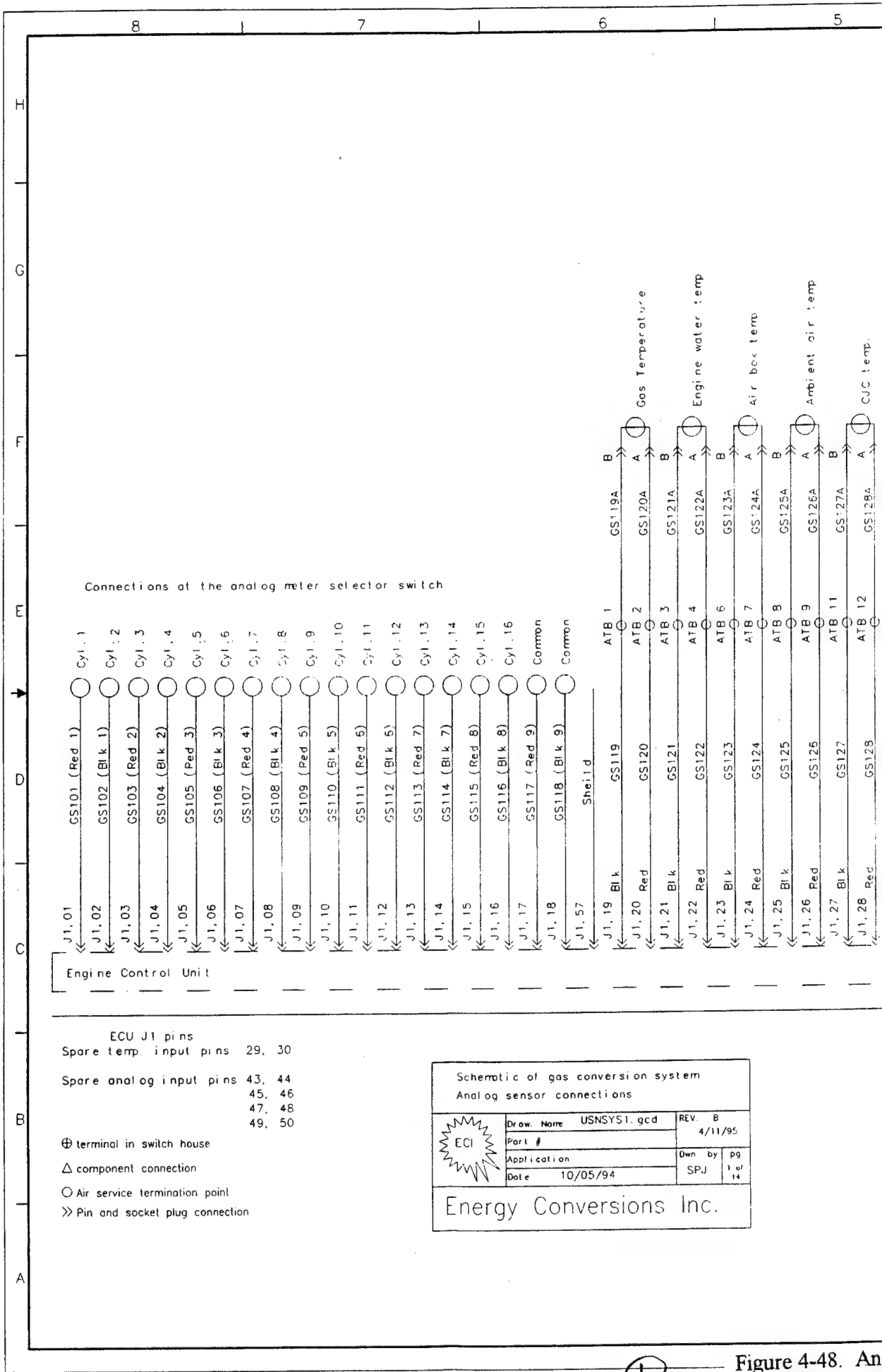


Description	Manuf.	Part number
pos metal shell	W n.	XMRA66PM-1000
/1 Exane 1000v	EW	1929U (030)
ld plated pins	W n.	100-1016P
at shrink	T&B	HVM187-9-1S

Gas conversion digital harness drawing and connections		
	Draw. Name	USNSYS9.GCD
	Part #	
	Application	
	Date	10/07/94
	REV. B	4/27/95
	Drawn by	SPJ
	pg.	9 of 14
Energy Conversions Inc.		

connections to ECU. SK - DO NOT SCALE  
Inc., U.S.A., 1996.)

QUANTITY FOR EACH ASSEMBLY	ITEM NO.	PART NO.	DESCRIPTION	MATERIAL
PARTS LIST				
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN FEET AND INCHES		DEPARTMENT OF THE NAVY NAVAL FACILITIES ENGINEERING SERVICE CENTER PORT HUENEME, CALIFORNIA 93043		
TOLERANCES .X DECIMALS .XX DECIMALS .XXX DECIMALS FRACTIONS $\pm 1/16"$ ANGLES $\pm 0.5^\circ$		DUEL FUEL 1500 KW CONVERSION OF DIESEL POWER PLANT SCHEMATIC OF GAS CONVERSION SYSTEM GAS CONVERSION DIGITAL HARNESS DRAWING AND CONNECTIONS		
PROJECT NO. DWG NO. USNSYS9.gcd DES. BY DR. F. DELLALBERA CHK. BY DRAWN BY R. MACK DWG. BY SATISFACTORY TO		SIZE CODE IDENT NO. F 80091 CONSTRUCTION NO. SPEC.		
APPROVED DATE COMMANDING OFFICER DATE APPROVED DATE FOR COMMANDER, NAVAL		SCALE NONE SHEET 1 OF		

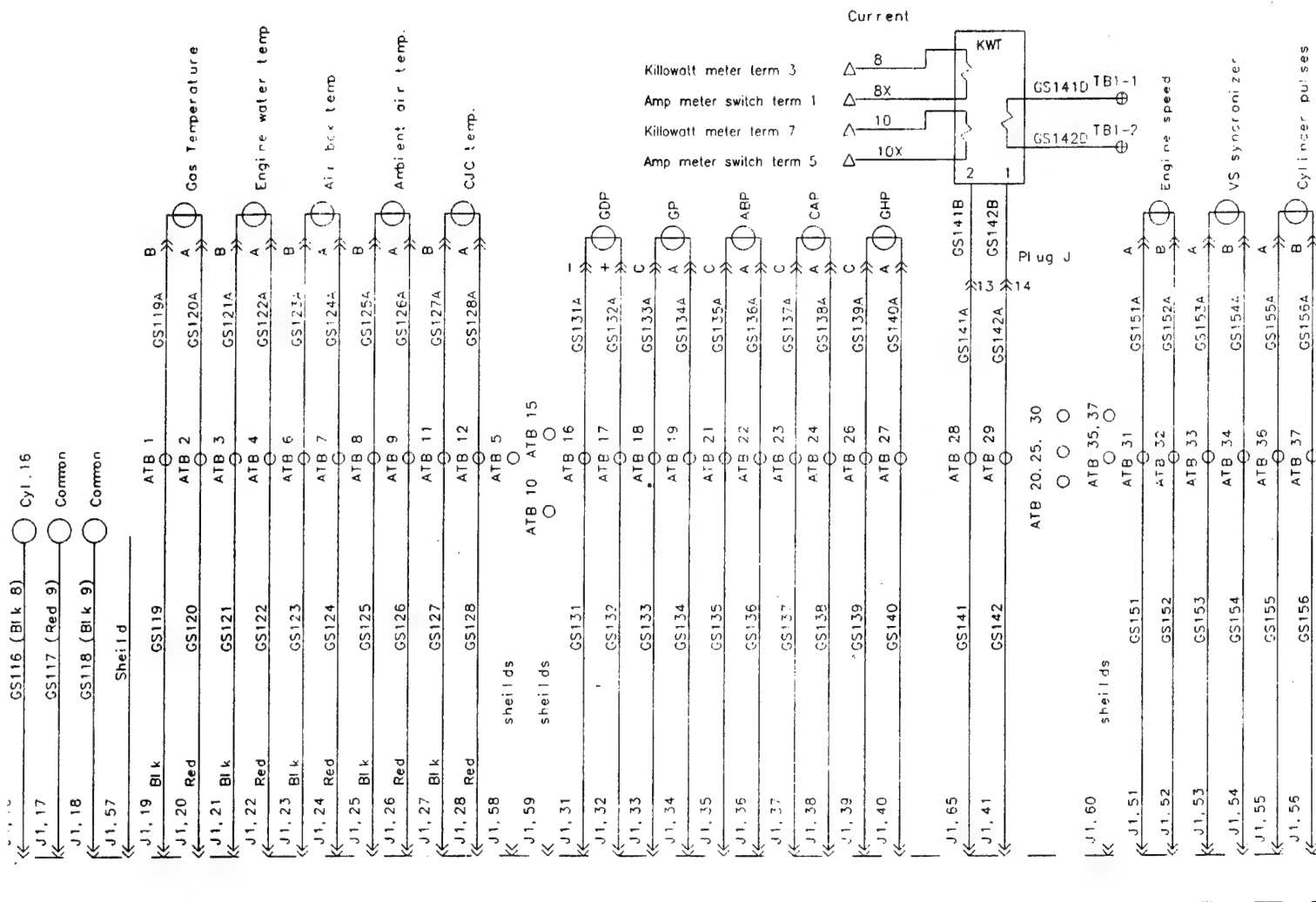


Schematic of gas conversion system  
Analog sensor connections

	Draw. Name	USNSYS1.qcd	REV.	B
	Part #		4/11/95	
	Application		Dwn by	pg
	Date	10/05/94	SPJ	1 of 14

Energy Conversions Inc.

**Figure 4-48. Ana**  
(Used by perm)



# tic of gas conversion system sensor connections

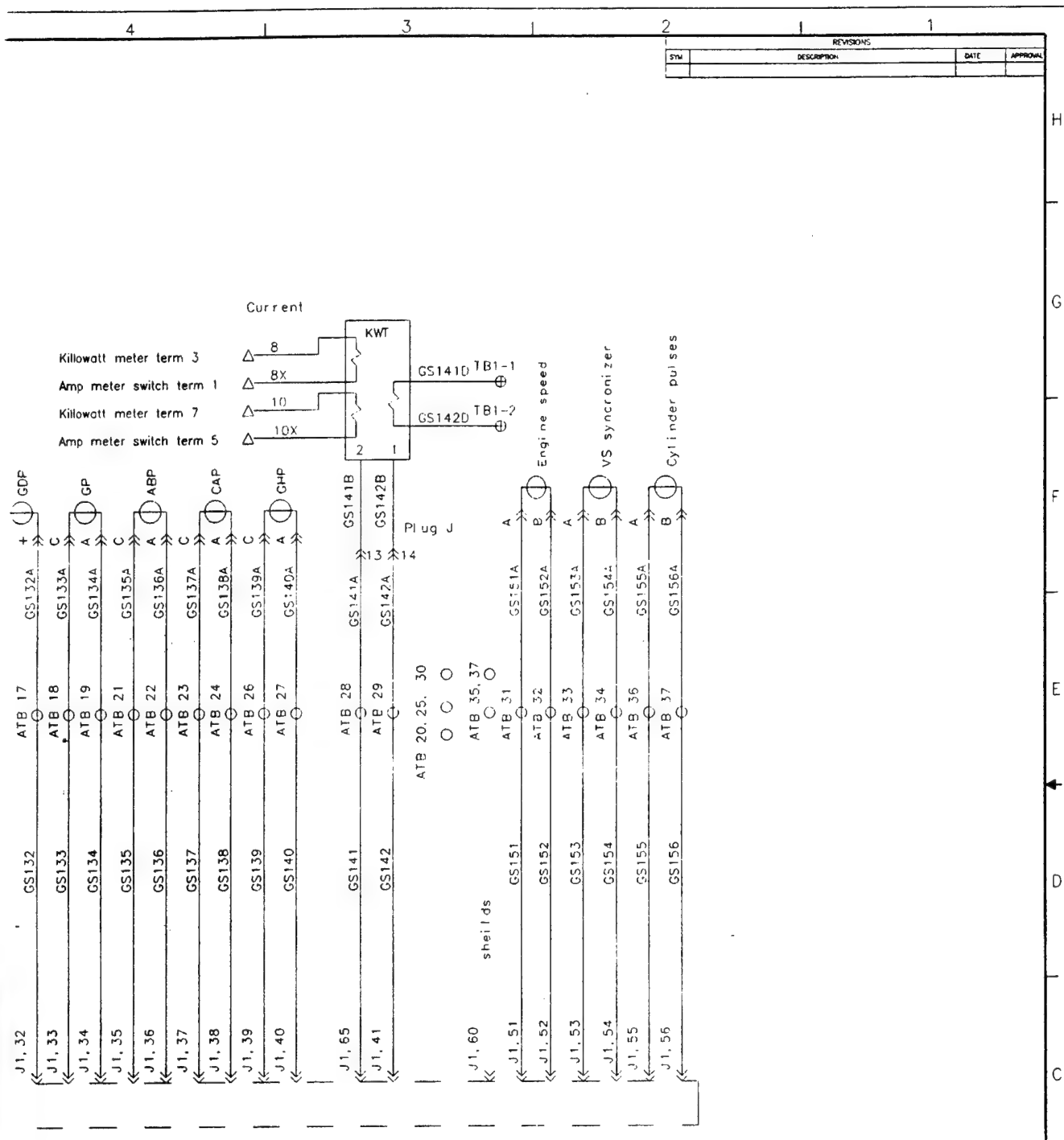
Draw. Name	USNSYS1.gcd	REV. B
Part #		4/11/95
Application		Dwn. by pg.
Date	10/05/94	SPJ 1 of 14

gy Conversions Inc.

QUANTITY FOR EACH ASSEMBLY		ITEM NO.	PART NO.
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN FEET AND/OR INCHES		PROJ. NO. ECI-DF-	
TOLERANCES:		DES. XX	
X DECIMALS		DIM. XX	
XX DECIMALS		BRANCH HEAD X MARK	
XXX DECIMALS		SATISFACTORY TO	
FRACTIONS ±1/16"		WIRE CUBIC FEET	
ANGLES ±0.5°		NORMAN HELGESON	
PART DISK NO.		APPROVED	
NEXT ASSY		COMMANDING OFFICER	
		APPROVED	
		FOR COMMANDER NAVAC	

Figure 4-48. Analog sensor harness connections to ECU.

(Used by permission, Energy Conversions, Inc., U.S.A., 1996.)



QUANTITY FOR EACH ASSEMBLY		ITEM NO.	PART NO.	DESCRIPTION	MATERIAL
		PARTS LIST			
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN FEET AND/OR INCHES		PROJ. NO. ECI-DF-1 ENG. NO. DR. F. DELLAMONICA CHK. XX BRANCH HEAD R. MACY DW. DR. SATISFACTORY TO MIKE CHILBERS NORMAN HELGESON DEC 1996 APPROVED COMMANDING OFFICER APPROVED FOR COMMANDER, NAVFAC			
TOLERANCES: X DECIMALS XX DECIMALS XXX DECIMALS FRACTIONS: 1/16" ANGLES: ± 0.5°		DEPARTMENT OF THE NAVY NAVAL FACILITIES ENGINEERING SERVICE CENTER PORT HUENEME, CALIFORNIA 93043 DUEL FUEL 1500 KW CONVERSION OF DIESEL POWER PLANT SCHEMATIC OF GAS CONVERSION SYSTEM ANALOG SENSOR CONNECTIONS			
PART NO. NEXT ASSY.		SIZE CODE 80091		NAVFAC DRAWING NO. CONSTRUCTION CODE NO. SCALE: NONE SHEET 1 OF	

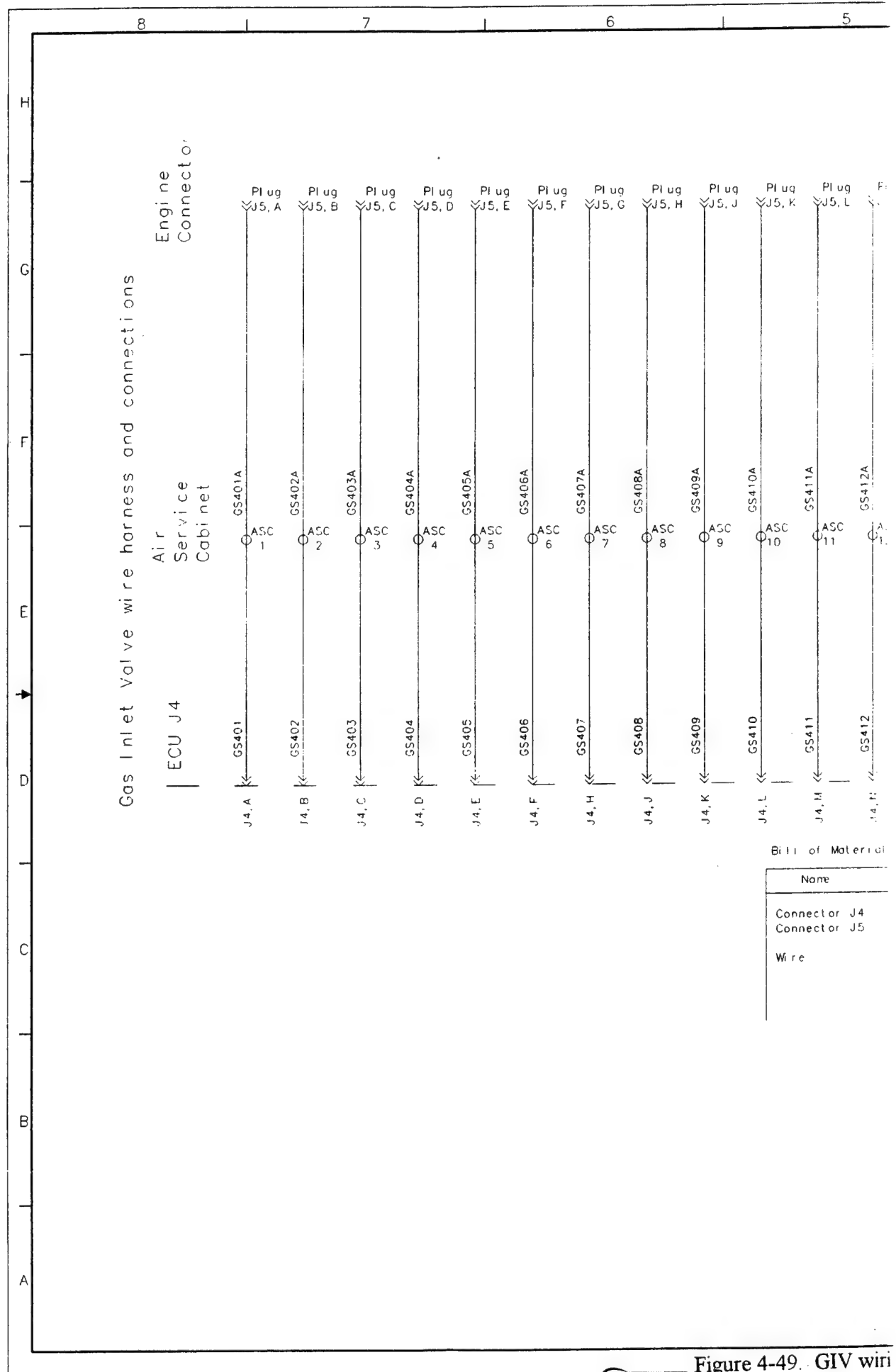
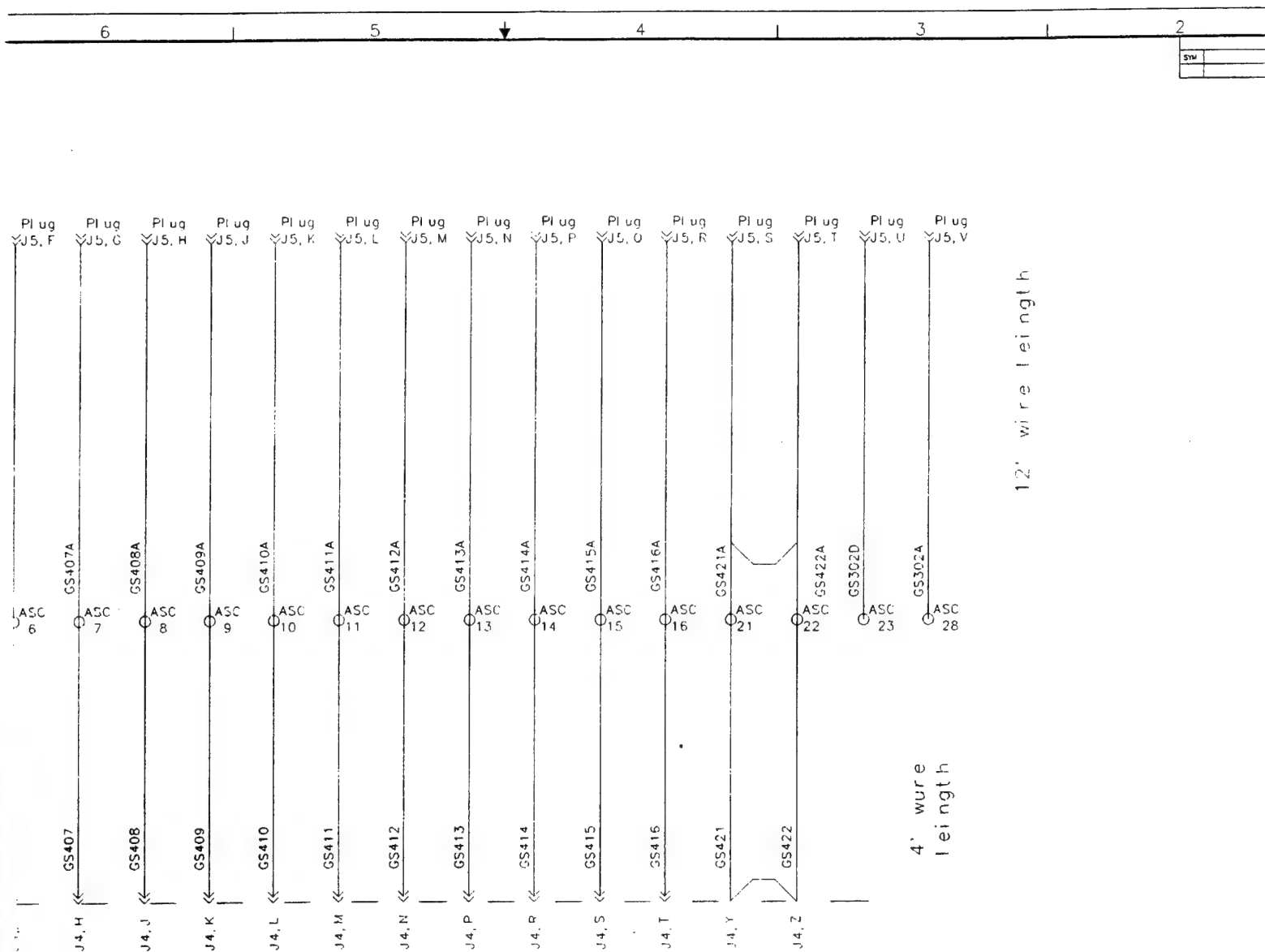


Figure 4-49. GIV wiring  
(Used by permission, Ercan)






Bill of Materials

Name	Qty.	Description	Manuf.	Part number
Connector J4	1	24 pos. metal conn.	Win. Ben.	XMRA24PM-1000
Connector J5	1	20 pos. Circular met.	Ben.	MS3108A 2816-S-A95
Wire	200	16 Ga. Exane 600V	E W	1929U (030)

Gas Inlet Valves harness and wire connections

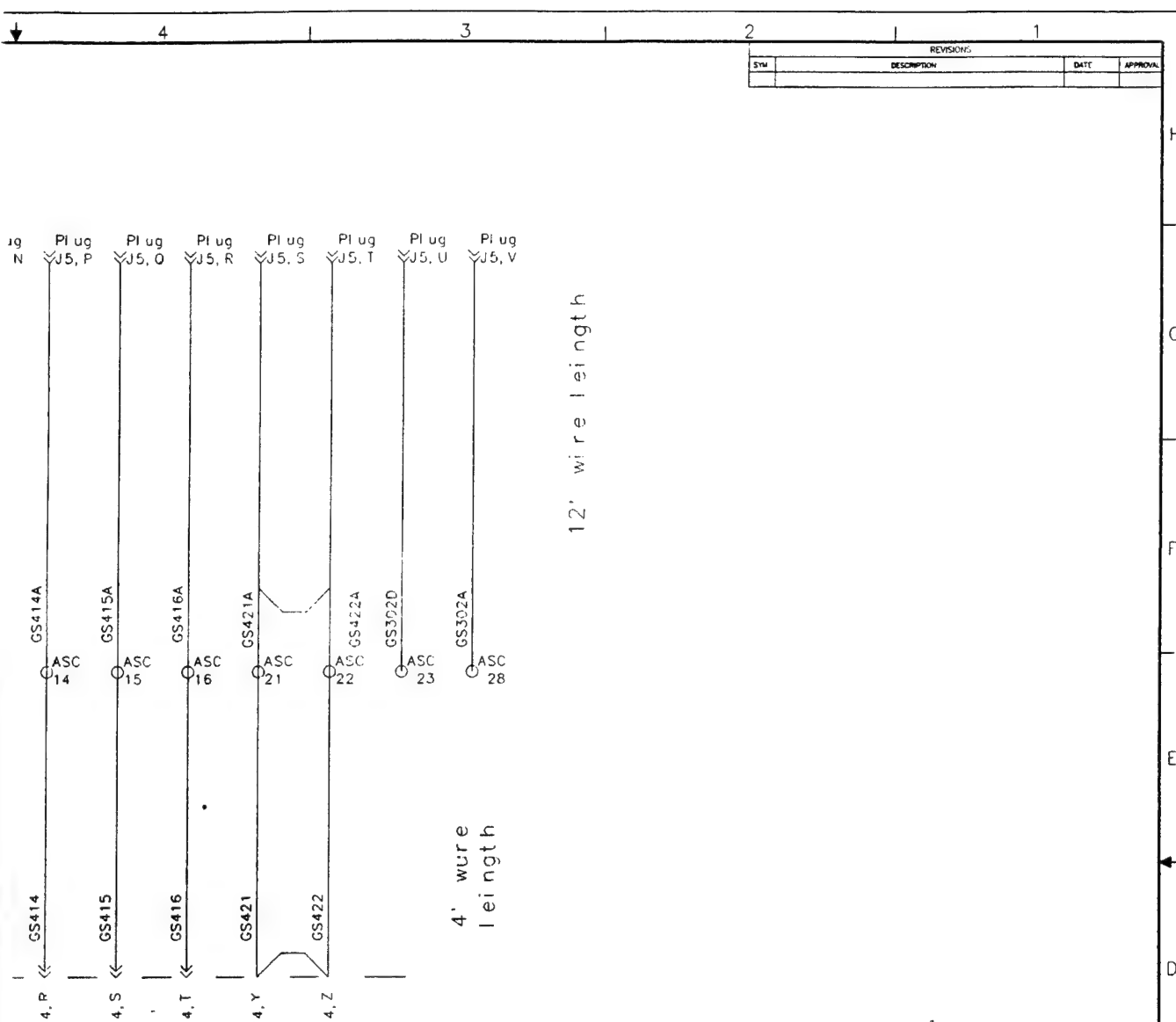
	Draw. Name	USNSYS10.GCD	REV. A
	Part #		1/17/95
	Application		Dwn. by
	Date	10/25/94	SFJ

Energy Conversions Inc.

ITEM NO.		PART NO.	
QUANTITY FOR EACH ASSEMBLY			
UNITS: OVERSIZE SPECIFIED DIMENSIONS ARE IN FEET AND/OR INCHES			
TOLERANCES X DECIMALS XX DECIMALS XXX DECIMALS FRACTIONS: $\pm 1/16"$ ANGLES: $\pm 0.5^\circ$			
PART DASH NO.		NEXT ASSY	
PROD. NO.		USNSYS10.gcd	
DES. XX		DR. T. DELLAMONICA	
CHK. XX		BRNCH. HEAD. K. MACEY	
DW. DIR.		SATISFACTORY TO	
APPROVED		DATE	
COMMANDING OFFICER		DATE	
APPROVED		DATE	
FOR COMMANDER R. NAVY			

Figure 4-49. GIV wiring harness connections to ECU. NO NOT SCALE

(Used by permission, Energy Conversions, Inc., U.S.A., 1996.)



description	Manuf.	Part number
4 pos. metal conn.	Win.	XMRA24PM-1000
0 pos. Circular ret.	Ben.	MS3108A 2816-S-A95
6 Ga. Exane 600V	E. W.	1929U (030)

Gas Inlet Valves harness and wire connections			
	Draw. Name	USNSYS10 GCD	REV A
	Part #		1/17/95
	Application		Dwn. by
	Date	10/25/94	SPJ
Energy Conversions Inc.			

QUANTITY FOR EACH ASSEMBLY	ITEM NO.	PART NO.	DESCRIPTION	MATERIAL
PARTS LIST				
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN FEET AND/OR INCHES TOLERANCES X DECIMALS XX DECIMALS XXX DECIMALS FRACTIONS ± 1/16" ANGLES ± 0.5°		DEPARTMENT OF THE NAVY NAVAL FACILITIES ENGINEERING SERVICE CENTER PORT HUENEME, CALIFORNIA 93043 DUEL FUEL 1500 KW CONVERSION OF DIESEL POWER PLANT SCHEMATIC OF GAS CONVERSION SYSTEM GAS INLET VALVES HARNESS AND WIRE CONNECTIONS		
APPROVED: _____ DATE _____ COMMANDING OFFICER APPROVED: _____ DATE _____ FOR COMMANDER, NAVFAC		SIZE CODE IDENT NO. NAVFAC DRAWING NO. F 80091 CONSTR COVER NO. SCALE INCHES SHEET 1 OF		

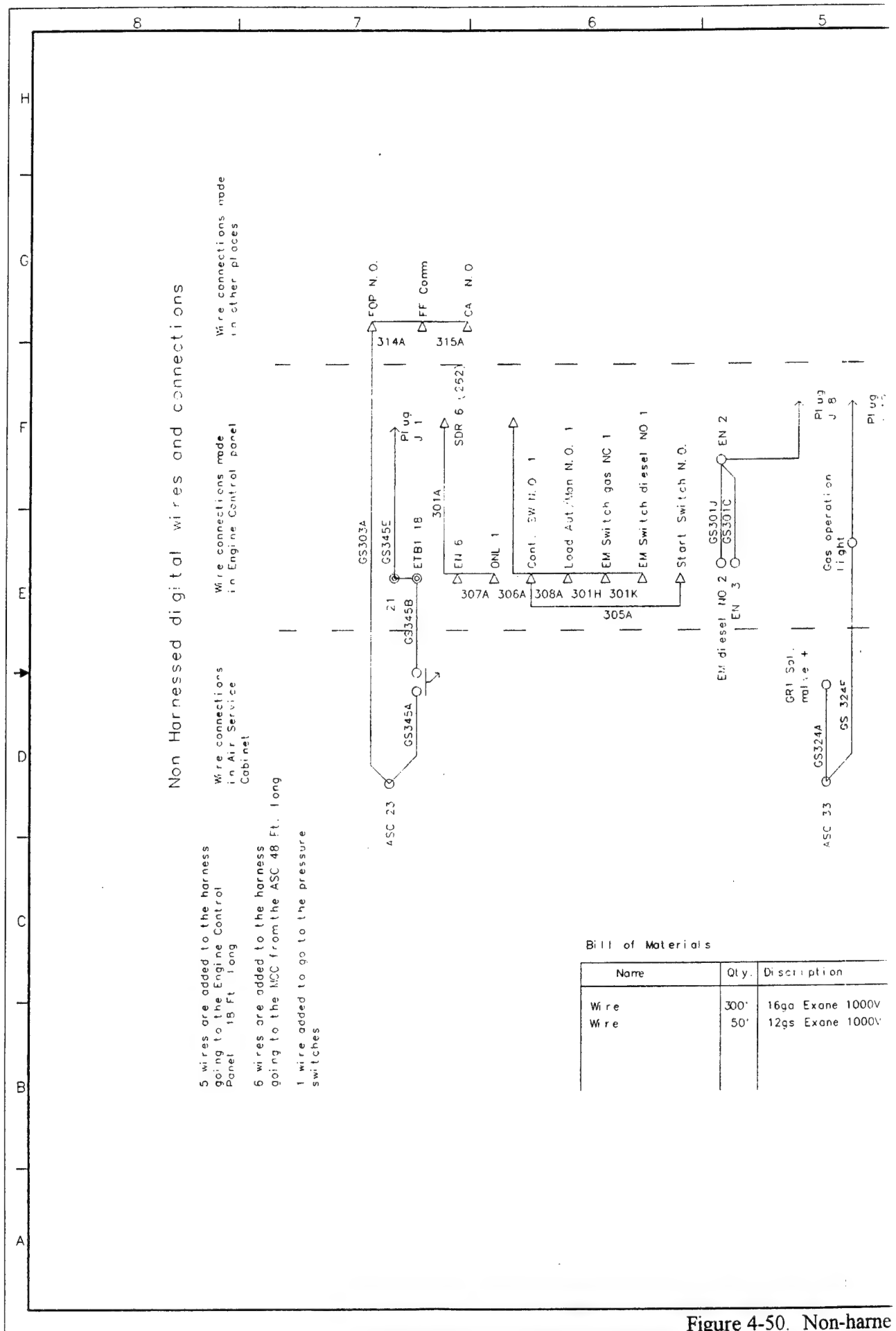
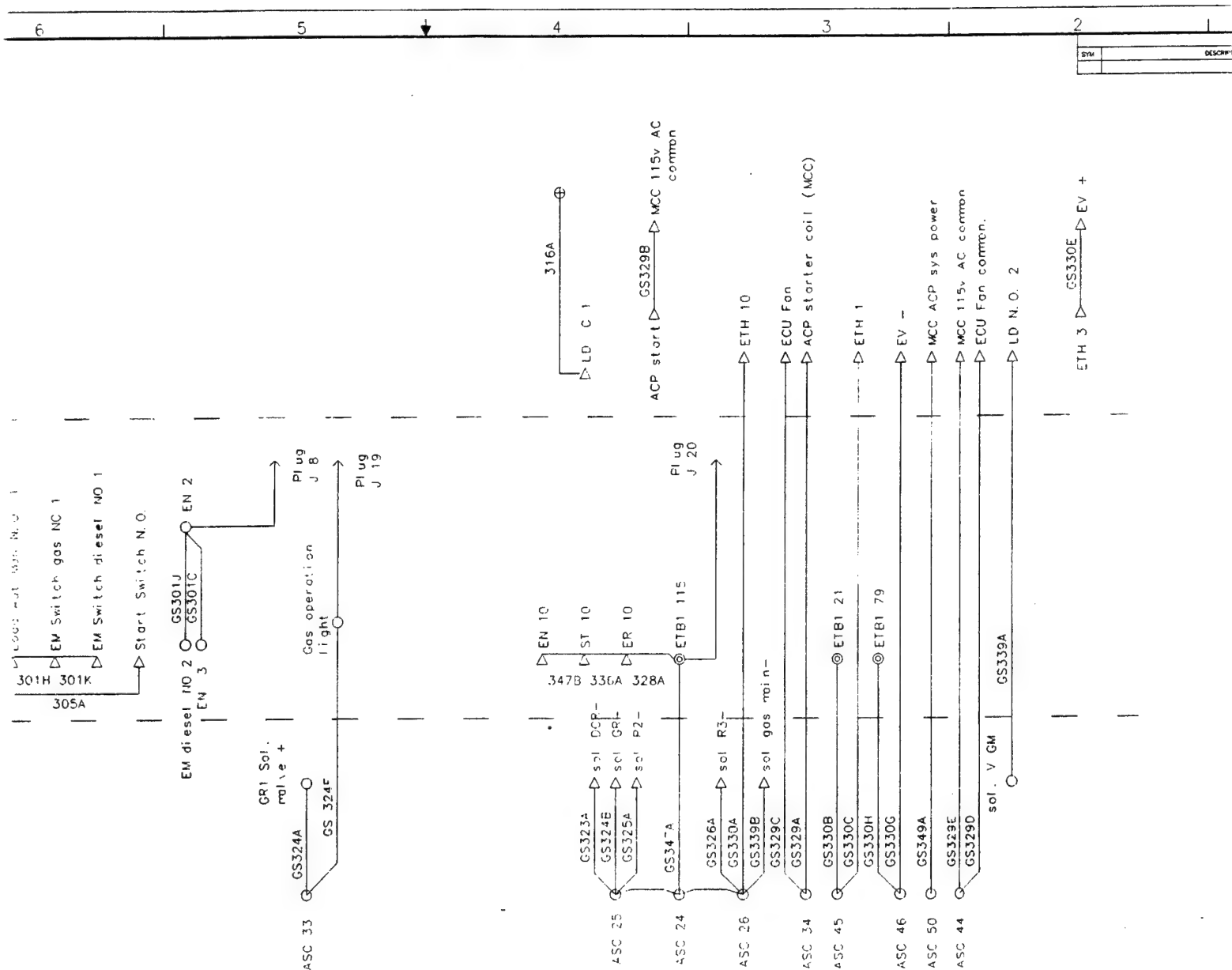


Figure 4-50. Non-harne  
(Used by permission, Energ)



Bill of Materials

Name	Qty.	Description	Manuf.	Part number
Wire	300'	16ga Exane 1000V	EW	1929U (030)
Wire	50'	12gs Exane 1000V	EW	

Gas conversion system non harness wire connections

ECI

Draw Name USNSYS12.GCD REV B 4/28/95

Pjrt #

Application

Date 10/27/94

Dwn by SPJ pg. 12 of 14

Energy Conversions Inc.

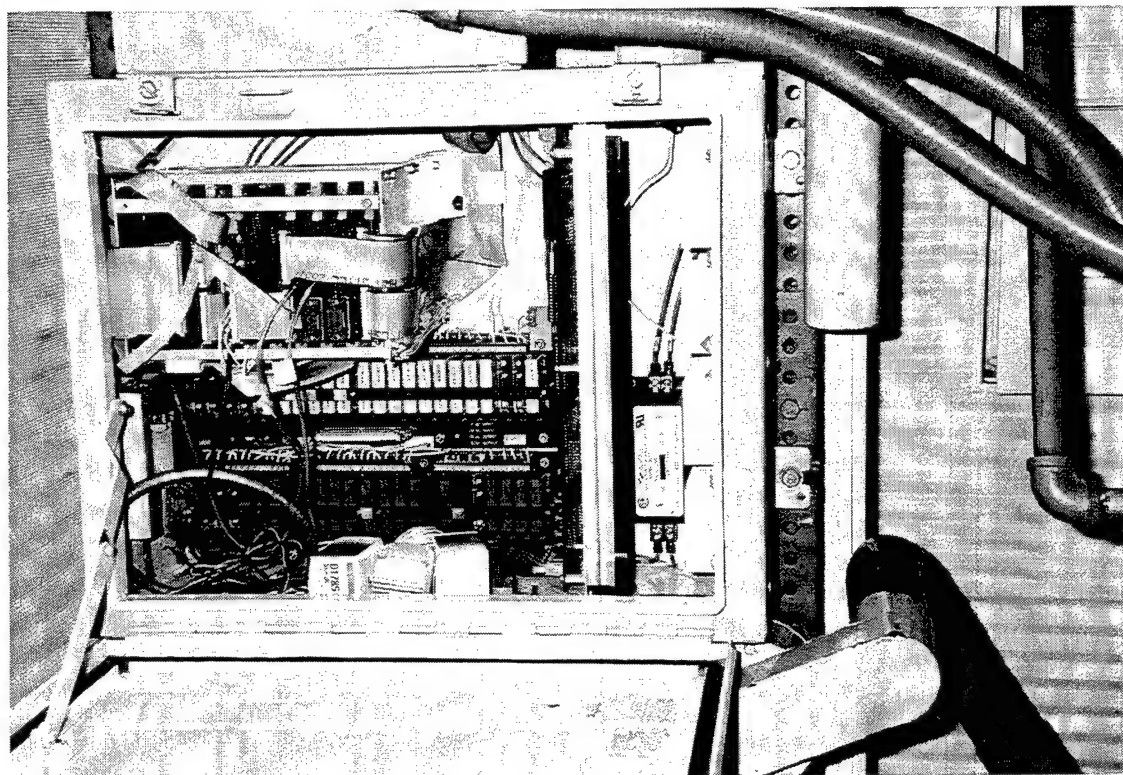
QUANTITY FOR EACH ASSEMBLY	ITEM NO.	PART NO.	DATE
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN FEET AND/OR INCHES	USNSYS12.gcd		
TOLERANCES	DOWNSIDE		
.X DECIMALS	DOWNSIDE		
.XX DECIMALS	DOWNSIDE		
.XXX DECIMALS	DOWNSIDE		
FRACTIONS	±1/16"		
ANGLES	±0.5°		
APPROVED	DATE	SCALE	800
FOR COMMANDER, NAVY	DATE	SCALE	800

Figure 4-50. Non-harness wire connections in ASC. DO NOT SCALE

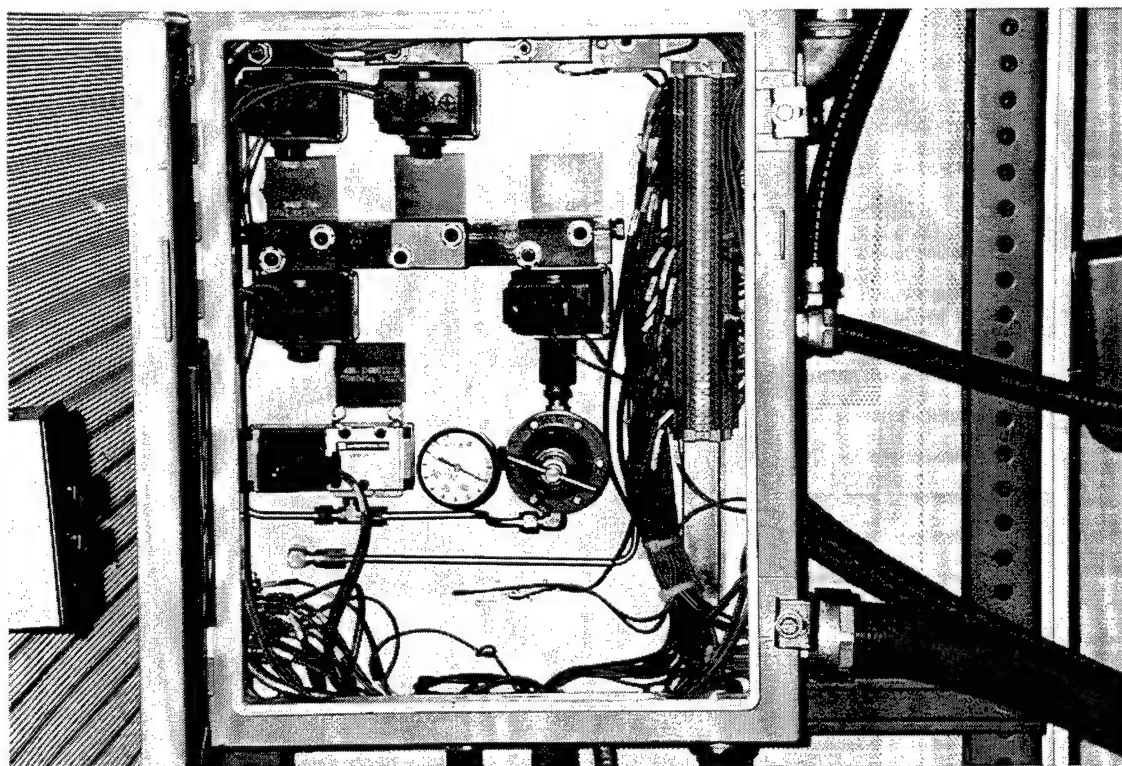
(Used by permission, Energy Conversions, Inc., U.S.A., 1996.)

2





(a) Internal view of ECU.

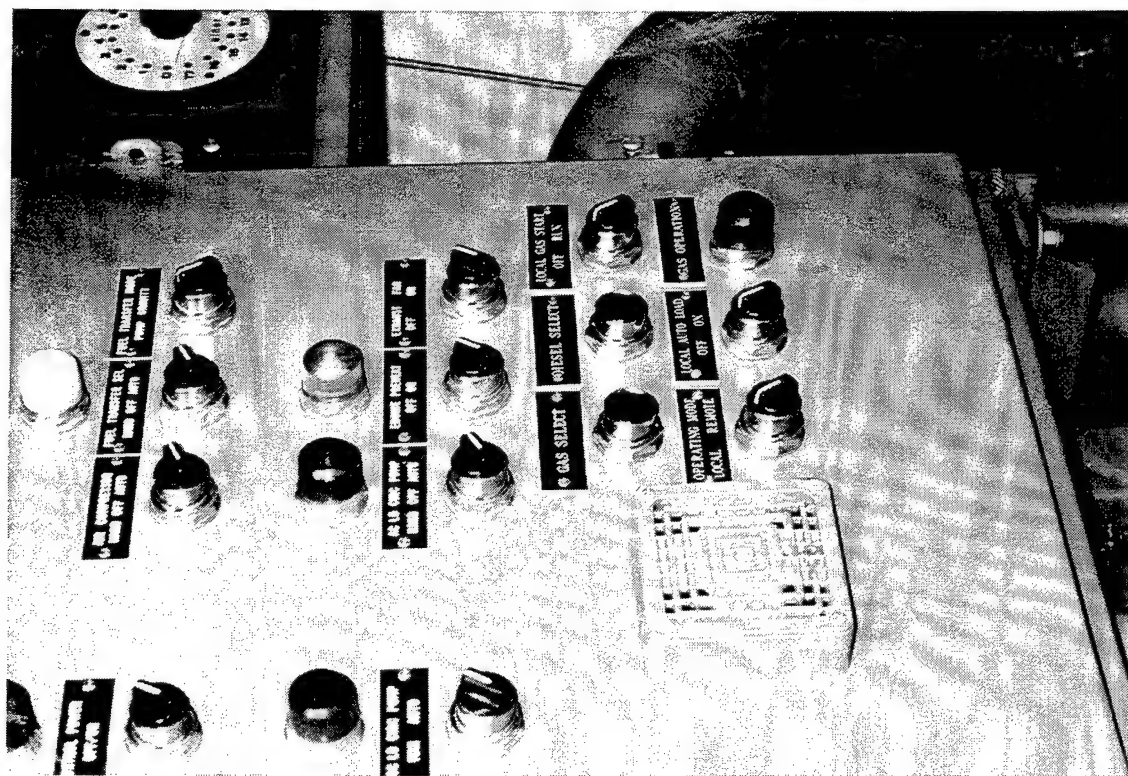


(b) Internal view of ASC.

Figure 4-51. Photographs of controller modifications.



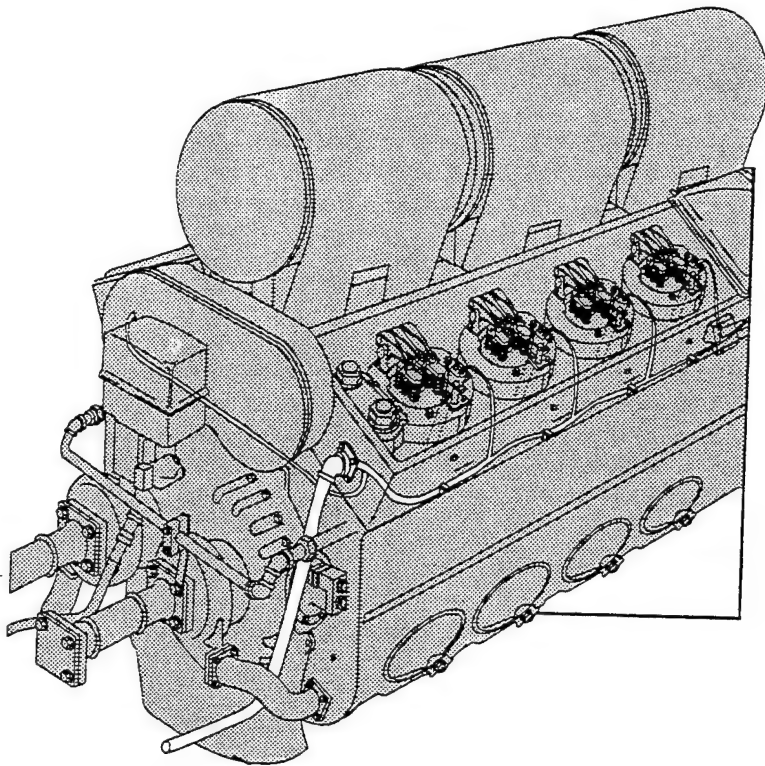
(a) ECP showing status screen (upper right) and gas detect alarm light.



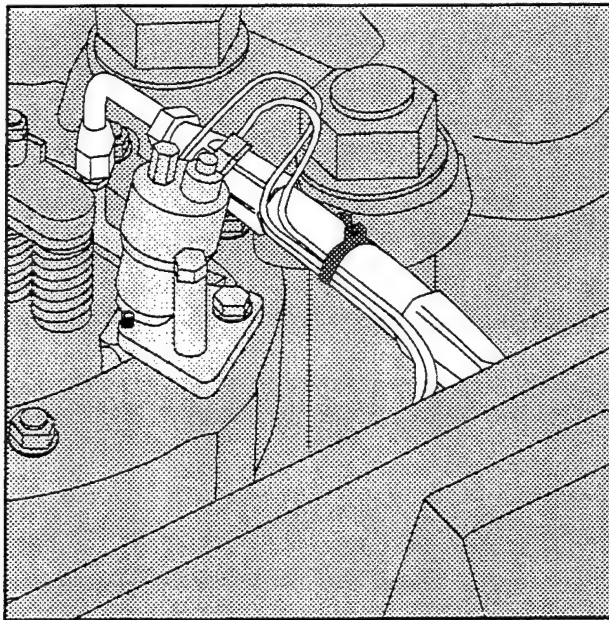
(b) ECP with modified selector switches.

Figure 4-52. Engine control panel (ECP) modifications.





(a) GIV wire harness from ASC to engine.



(b) Wiring connections for GIV-actuating signal and for temperature monitoring of GIV.

Figure 4-53. GIV electrical hookup.  
(Used by permission, Energy Conversions, Inc., U.S.A., 1996.)



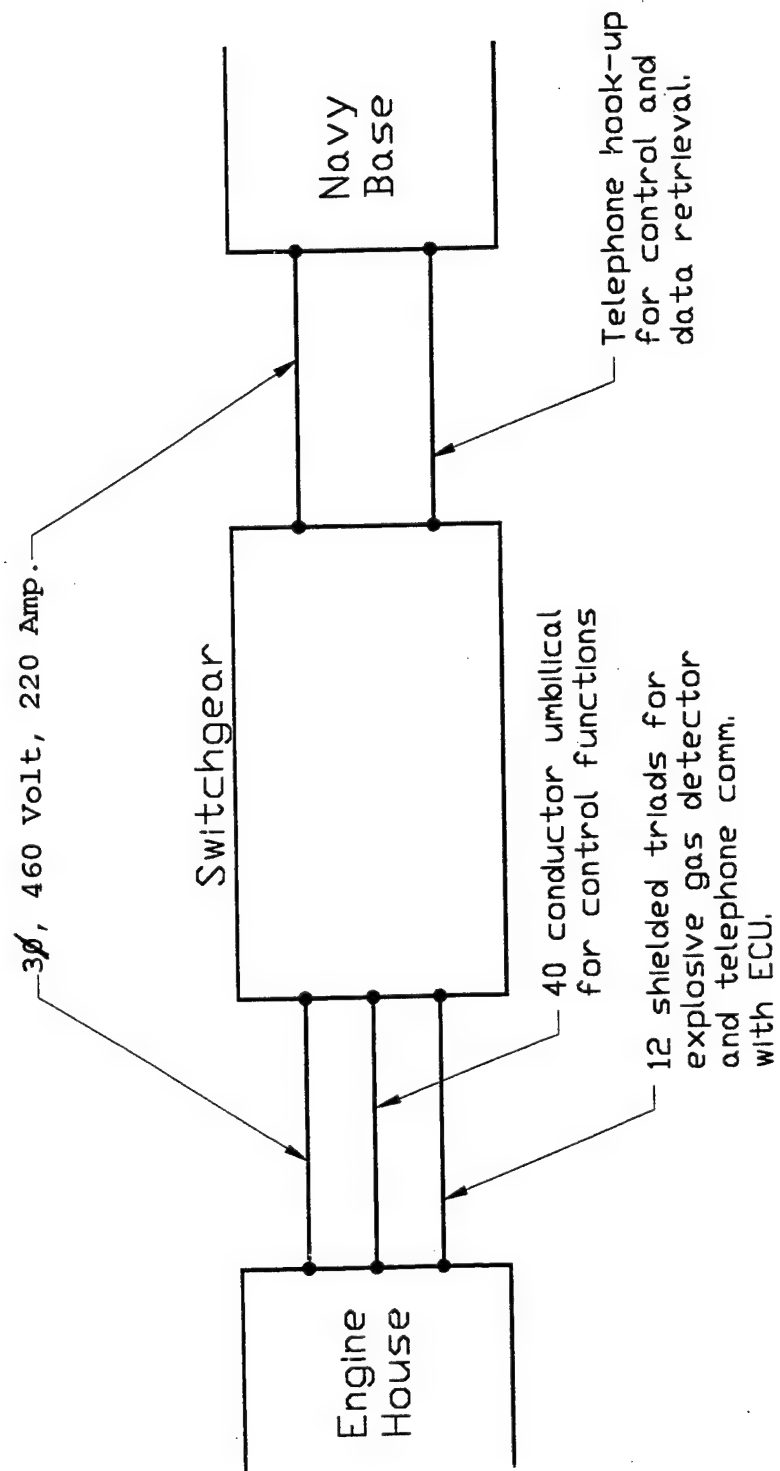
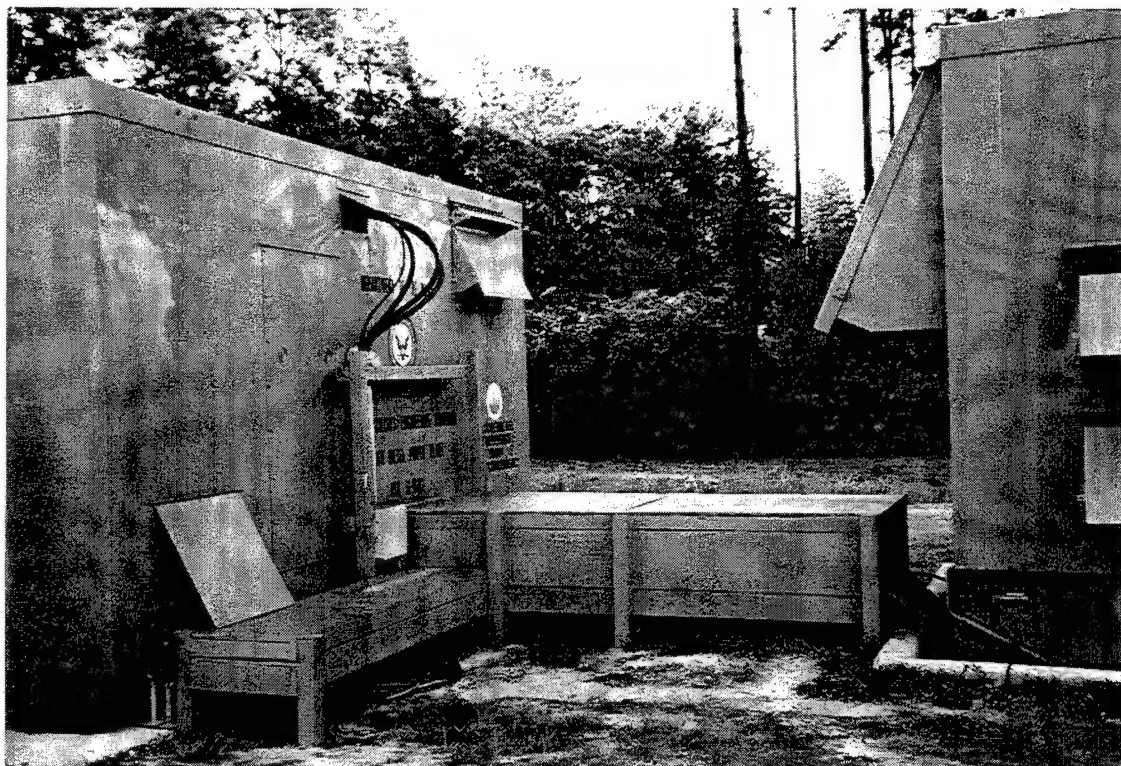


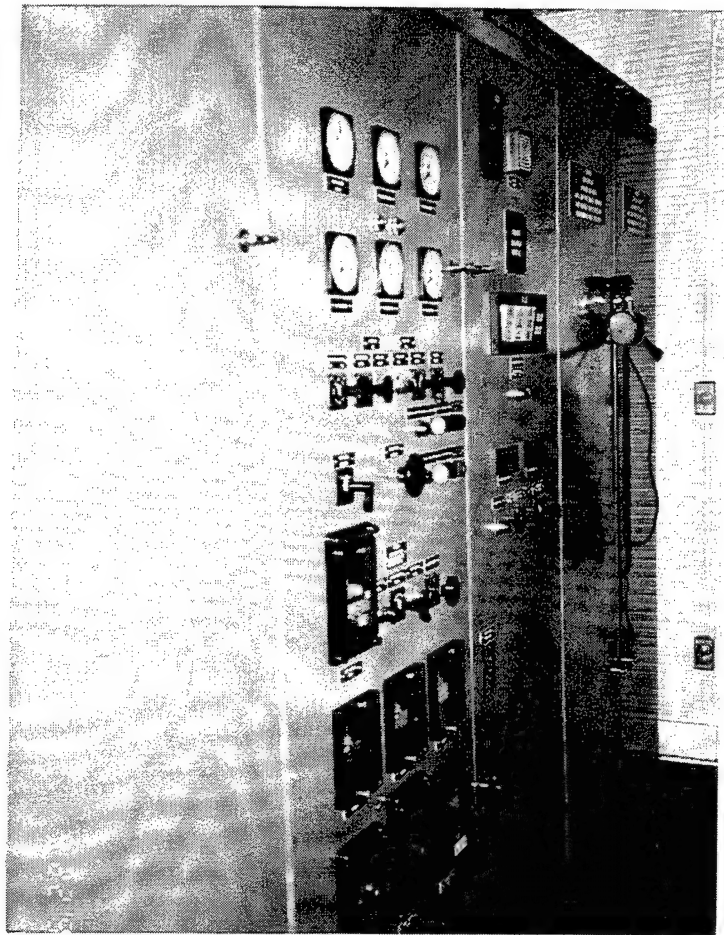
Figure 4-54. Schematic diagram of electrical interconnect to switchgear.



(a) Switchgear installed and wiring in place.

Figure 4-55. Photograph of gas conversion components in switchgear house.

(b) Switchgear control panel.



(c) Added selector pushbuttons and indicating lights for gas conversion.

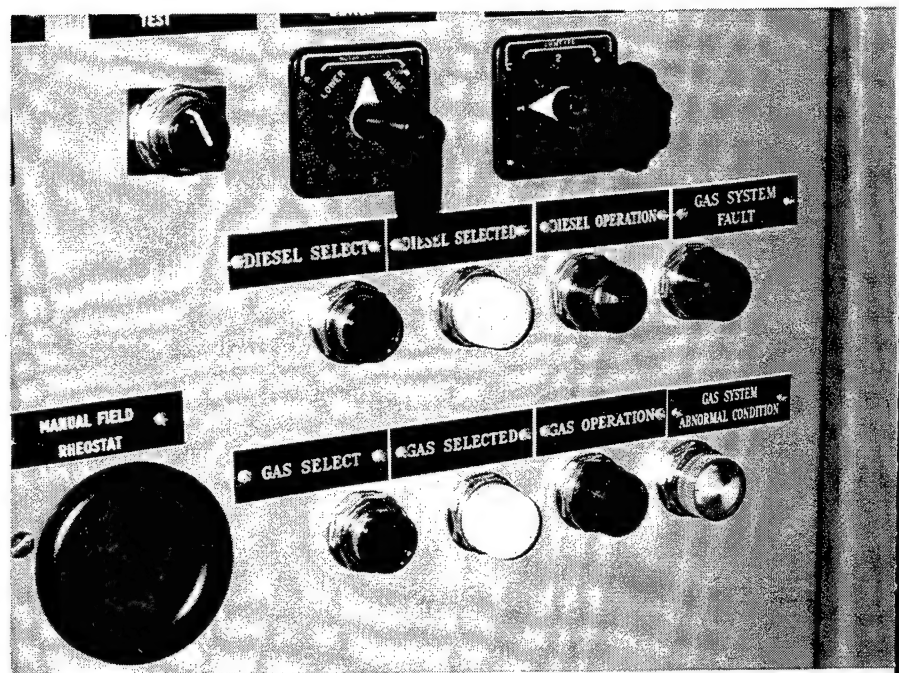
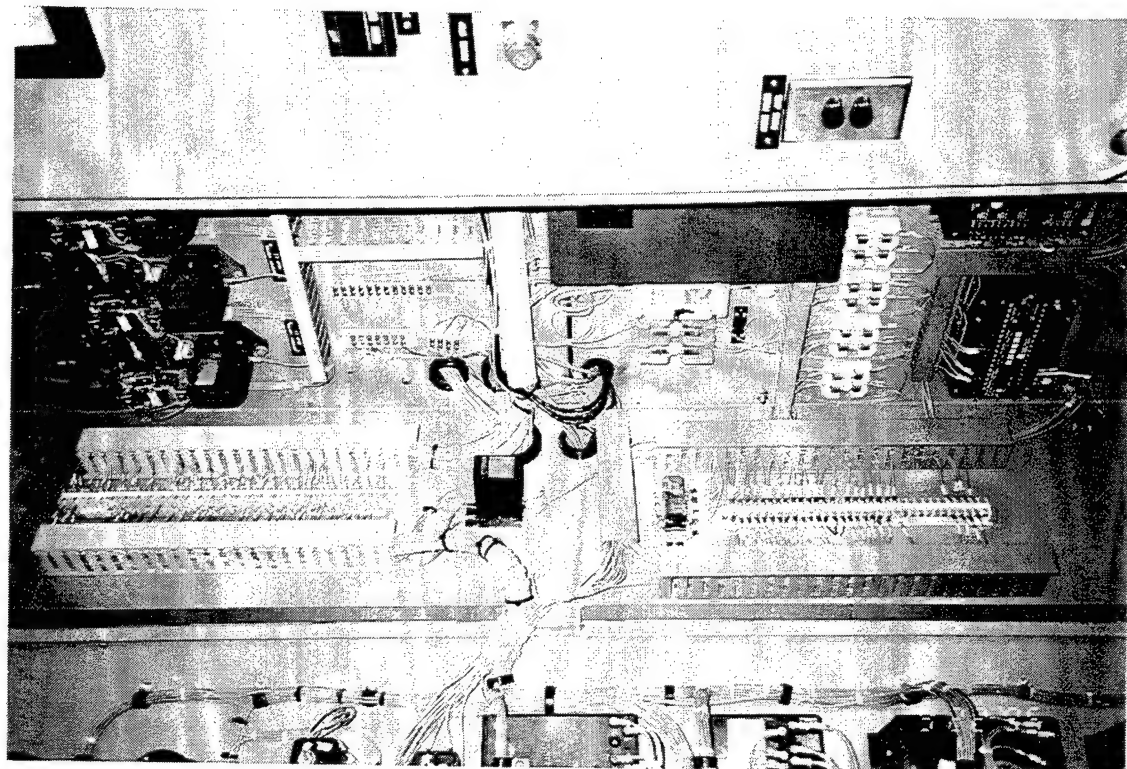
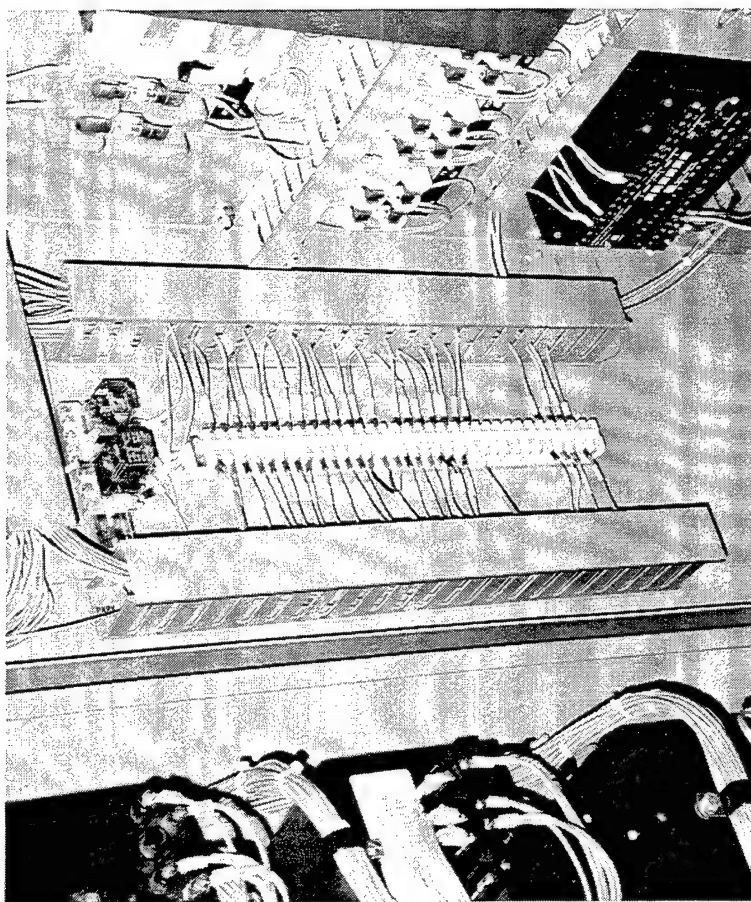


Figure 4-55. Photographs of gas conversion components in switchgear house. (Cont'd.)

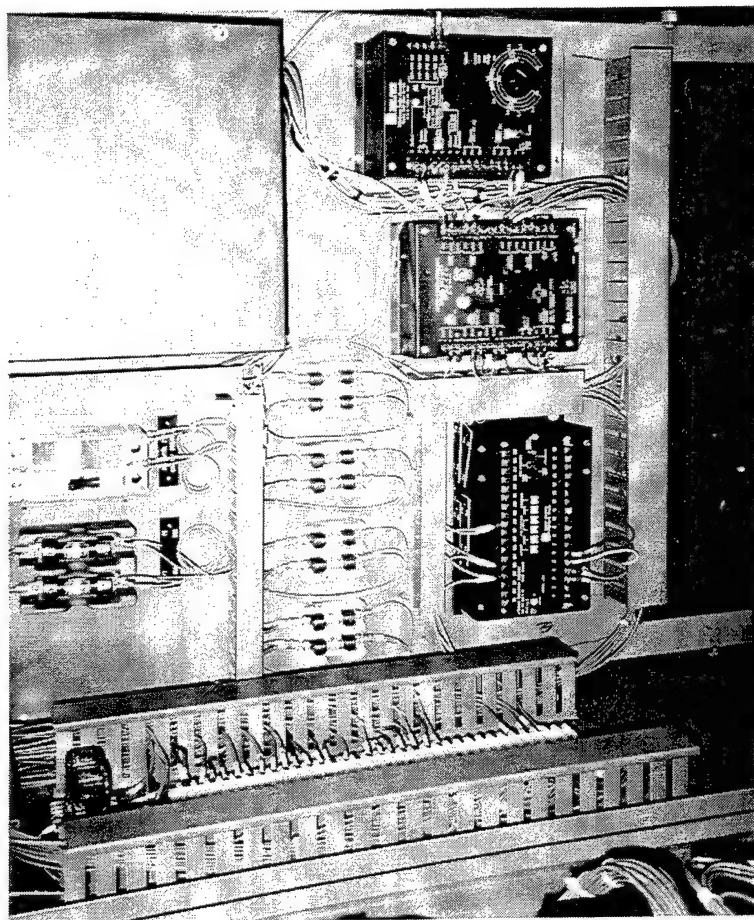


(d) Internal view of switchgear wiring.

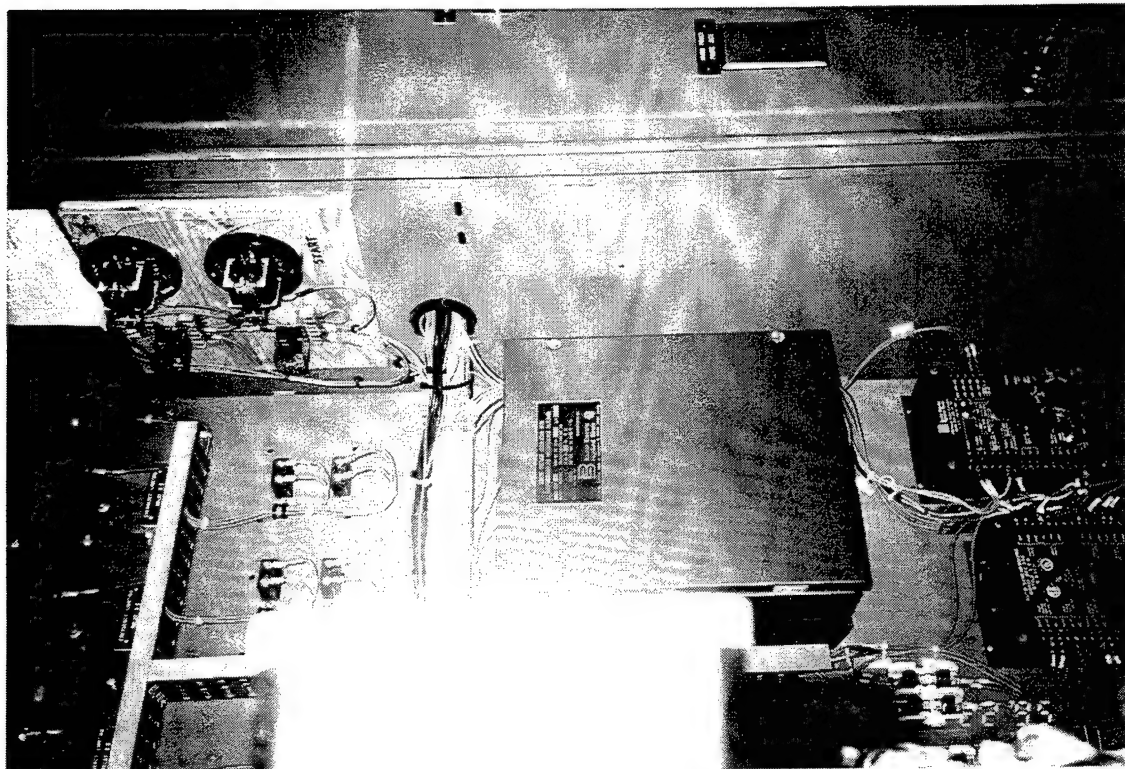


(e) Gas conversion terminal strip.

Figure 4-55. Photographs of gas conversion components in switchgear house. (Cont'd.)



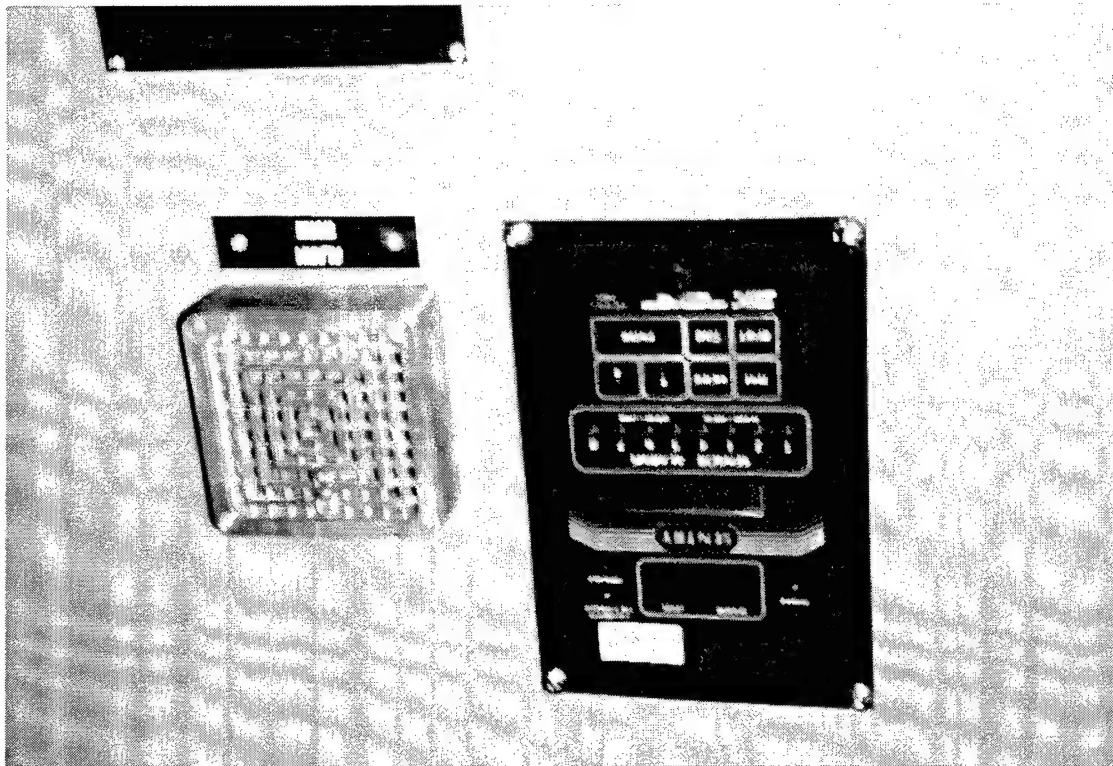
(f) Reference adjuster, auto-synchronizer, and power factor controller for remote, auto-synchronization of generator set to electrical grid.



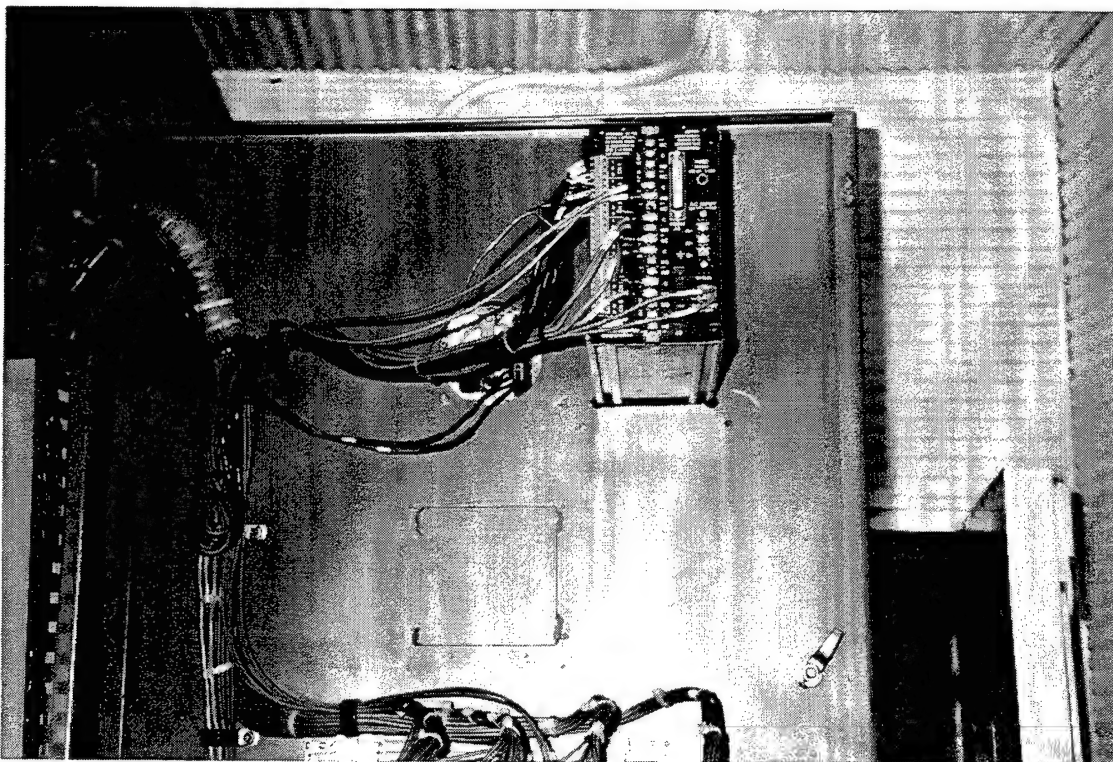
(g) Telephonic relays for remote start/stop.

Figure 4-55. Photographs of gas conversion components in switchgear house. (Cont'd.)





(h) Hazardous gas controller module.



(i) Controller module installed and wired in to two hazardous gas sensors in engine house.

Figure 4-55. Photographs of gas conversion components in switchgear house. (Cont'd.)

## **5.0 OPERATIONAL PROCEDURES**

Operation of the converted dual fuel MUSE engine generator set can be by either diesel or diesel/natural gas mode of operation. It can be controlled from the on-site engine control panel (ECP) or switchgear panels (SGP) or from a remote site. It can operate as either a stand-alone electrical generating station or be synchronized with and provide power to an electrical grid at 4,160 volts.

### **5.1 Diesel Only Operation**

Diesel operation can be by (a) manual, (b) local automatic, or (c) remote automatic control. Manual operation utilizes the existing ECP. Selector switches on the ECP (Fig. 4-2(b)) are appropriately set for manual diesel operation. The engine is started and brought to speed by the operator who must verify temperature, pressure, engine speed, and other measurements as the unit warms and is brought to operating speed. The unit is then synchronized with the power grid (voltage, frequency, and phase angle), the breaker is closed, and the unit is loaded to the desired power level. All of these manual operations are performed in the same manner as for a MUSE diesel engine generator that has not been converted to dual fuel operation.

The addition of the ECU as part of the installation of the dual fuel system has made it possible to operate the unit in a completely automatic mode. The automatic mode of operation is also set by selector switches on the ECP. In this mode of operation the actuation of a single 'start' switch initiates the sequence of actions required to proceed through all steps to start the engine, close the electrical breaker to the electrical grid, and load the unit. Actuation of the 'stop' switch causes the reverse of this procedure and brings the unit to a stop.

The actions that take place during remote automatic control are identical to those for local automatic control with the exception that the 'start' and 'stop' switches are at a remote location and that an additional computer status screen is provided at the remote site. The details for using the automatic mode of operation are discussed in the sections below.

### **5.2 Natural Gas (Dual-Fuel) Operation**

Natural gas operation refers to dual-fuel operation where approximately 95 percent of the fuel required to run the engine generator set is provided by natural gas. About 5 percent is diesel fuel that is used as an ignition source for the natural gas charge.

Natural gas operation requires automatic control. Manual 'local' control is not an option. This is because operation in the natural gas mode requires several operations in the startup and run routines that are essential but are not easily performed in the manual mode. It is also because automatic operation serves to ensure that conditions for which safety interlocks are provided for natural gas operation are satisfied prior to natural gas firing. The engine is always started in the diesel mode and only after the engine has been started and reaches a speed of 900 rpm (the normal operating speed is 900 rpm) is the unit transferred to natural gas operation. Similarly, the engine automatically transfers from natural gas to diesel operation at 900 rpm before coming off line.

When the unit is on-line and generating power, it may transfer from natural gas to diesel operation for any of several 'faults' that can arise. If a fault corrects itself during the course of the operation a return to natural gas operation can automatically occur. Other faults may cause permanent transfer to diesel operation or may cause immediate shutdown of the unit. Transfers from diesel operation to natural gas, and the reverse, normally occur automatically and without interruption of power generation.

### 5.3 Automatic Control

The autostart flow chart is shown on Figure 5-1. Autostart can be initiated from either a remote site or from the ECP. Several software routines and parameters are included in the autostart. Nine time-parameters, indicated in the lower right-hand corner of Figure 5-3, indicate the various time intervals involved in the startup procedure. In Step 2, after receiving a 'Start' request, Autostart first verifies that the engine is not running. A leak detection system check is then made in Step 3 to ensure that no combustible species are present in the air space of the engine house. The exhaust fan is then turned on and an air flow measurement is made to verify proper operation of the exhaust blower. At that point the main gas valves (V1 and V2, see Fig. 4-7) and the GCOV Fig. 4-10) are opened briefly to charge natural gas to all of the lines downstream of V1 and V2. V1 and V2 are then closed and the pressure in the downstream line is monitored for T3 seconds. No change in pressure indicates that gas line integrity is adequate to proceed. GCOV is then closed and V1 and V2 are opened. At this point the controller walks the engine through its normal start-up procedure by pre-lubing it, sounding the starting alarm, barring the engine for T6 seconds, and after a check to ensure that all parameters are in their proper ranges for starting as indicated by the Ready-to-Start (RTS) relay, cranking the engine (Step 16). After starting, the controller ramps the engine up to operating speed with continuous signals to the governor (GUP). At 900 RPM the synchronizer is enabled and the generator is brought into synchronous operation with the electrical grid by utilizing feedback signals from the synchronizer to the controller. These signals cause adjustment of engine speed by providing signals to the governor (GUP or GDN). The electrical breaker to the grid is closed upon synchronization and the controller then proceeds to increase the electrical load on the generator until it reaches the desired operating level (normally 1,500 kW). The engine automatically changes to NG operation as the load passes through 300 kW.

Any of several reasons will cause the engine to be stopped. These include the detection of a hazardous gas within the engine space, a failure of the exhaust fan, the opening of a valve temperature switch, or receipt of a 'Stop' signal. Other faults may cause operation of the engine to shift to diesel fuel operation until any out-of-specification variables return to acceptable values.

**5.3.1 Autostart Software.** Software functions important to the automatic starting and running of the engine generator set are discussed below.



**Basic Gas Engine Operation.** This routine defines the engine mode so that it will switch to gas operation if all prescribed variables are in order. The controller monitors all engine, gas system, and electrical parameters to ensure that each is in the prescribed range for gas operation. Out-of-range parameters may cause the engine to automatically switch to diesel operation until the variable returns to an acceptable value.

**SY.** This routine enables the controller to turn AC power on to the synchronizer and causes the synchronizer to send signals to the controller to speed up or slow down the engine. As electrical synchronization is achieved, the synchronizer causes the main circuit breaker to close.

**ER.** The engine run relay must be opened to activate a control circuit that keeps the engine running. Its closing causes the engine to shut down.

**CNK.** The crank engine routine energizes the start relay that causes the starter motor (driven by compressed air) to spin. The controller holds the start relay on for a maximum of 20 seconds with the expectation that the engine will start in that time and that engine speed will increase above a threshold value of 200 RPM. At this point the controller disables the CNK signal and begins performing other control functions. If the engine fails to start, the controller attempts to again start the engine after waiting for one minute until the starting air pressure builds to a satisfactory level. The controller again recycles through the pre-lube and engine barring steps before attempting the restart.

**RTS.** The ready-to-start signal is required before the engine starting sequence can commence. The controller will wait for a maximum of 5 minutes following initiation of the engine barring procedure to activate an RTS signal. A longer time interval will cause a fault to be displayed and a lock-out from gas operation.

**Electrical Mode Determination.** This routine allows the controller to determine whether the unit is operating as a single generating unit or is paralleled to a buss. To accomplish this the controller first increases the speed set point of the engine slightly while monitoring speed and load. If load increases, the unit is determined to be paralleled and the controller will work to load the engine to its set point power rating. If speed increases, the controller determines that the unit is operating singly and will work to maintain a engine speed of 900 RPM (equal to 60 Hz).

**Gas Pressure Test.** Before the full gas supply is allowed into the engine house the gas pressure test must prove successful. An initial condition is that the engine must not be running. The engine controller must then receive a start signal either from the remote control center or from the engine control panel. It will then turn on the ventilation fan and monitor both the ventilating air flow signal and the leak detection signal. When both of these responses are satisfactory, the controller will send signals to open the GCOV and the gas main valves (V1 and V2). In approximately three seconds it closes V1 and V2 but keeps GCOV open. The controller waits a short period of time for pressures to stabilize across the GFCV and then reads pressure signals from the two gas pressure transducers. The readings must be within 5 percent of each other and above 50 PSI. The controller then waits 60 seconds and again reads the two pressure sensor signals. The signals must again be within 5 percent of each other and not more than 5 psi

less than the first reading. Such a test constitutes a passed pressure test. At that point the GCOV is closed and V1 and V2 are opened in anticipation of running on gas. If the test fails because no gas was admitted to the system, the controller will start the engine and operate it on diesel fuel. The ECU will indicate "Low gas pressure...test failed". If the test fails due to dropping gas pressure the ECU will indicate "Failed Gas Pressure Test". For the latter, a site inspection and system reset is required before further gas operation. In the event that the ECU does not receive satisfactory signals for the fan flow and leak detection measurements, it will indicate such and will not perform the gas pressure test and will not start the engine.

**GIV Sequencer.** The valve sequencer board inside the ECU processes input signals from the flywheel sensors and controls the GIV (gas inlet valve) timing. The valve sequencer processor (VSP) operates the GIVs when it receives an enable signal from the main controller. It then returns a signal to the main controller indicating that operation of the GIVs is satisfactory. If the main controller asks for GIV operation and the VSP does not return its status operational signal, gas operation is prevented and the main controller displays a valve sequencer fault on the status screen.

The VSP is programmed to examine crankshaft input signals for clarity and operational limits. If the VSP detects defects it will not operate the GIVs. However, the VSP is programmed so that if the signal defects are corrected it will resume operating. The main controller determines if too many faults have been detected by the VSP to continue gas operation. If gas operation is unsuccessful after a given number of attempts, the main controller stops attempting to initiate gas operation. Causes of problems detected by the VSP are displayed by four indicating lights on the board itself. The door to the ECU must be opened to view these lights.

**5.3.2 Alarm Logic.** In order for the ECU to allow gas operation the conditions indicated on the Alarm Chart (Table 5-1) must be met. If any of these conditions are not met the ECU will transfer operation to diesel operation. When the ECU determines that the conditions are once again within operating range, gas operation will continue. In order for an alarm to occur, the signal must fall outside of either the high or low limit. The alarm condition is cleared once the signal either rises above the 'low alarm clear' limit or falls below the 'high alarm clear' limit. Once the alarm is cleared, the ECU will wait for a 'time off after clear' period before resuming gas operation. If too many faults occur within a set period of time (# faults before long pause), the ECU will wait for the 'long pause time' before resuming gas operation. If this sequence occurs more than 'max # of pauses before lockout,' the ECU will not allow further gas operation until the problem has been resolved.

**5.3.3 ECU Status Messages.** The ECU decides when to switch between diesel and dual fuel operation based on predetermined limits for rpm, temperatures, pressures, switches, etc. The status of gas operation is displayed on the status screen. The screen automatically displays faults and conditions as they occur. The messages that appear on the status screen and explanations of them are as follows.

**Values in Normal Range - On/Off Gas.** This message will occur when the ECU is either on gas or ready to go on gas - all system parameters are within acceptable limits.

**Abnormal Values - On/Off Gas.** This shows a list of all values that have exceeded their normal range. Some may not be critical to gas operation (e.g., Ether left in canisters).

**Gas Operation Suspended...or Gas System Fault....** Both of these messages have the same result - the engine will resort to diesel operation. Gas Operation Suspended indicates that there is no need for concern. (e.g., WT - 100.0 shows that the ECU is waiting for the water temperature to rise.) Gas System Fault indicates that the engine is not operating properly (e.g., WT - 210.0 would indicate that the water temperature is above safe operating limits.) The engine will resume gas operation when the value falls returns to an acceptable range.

**ECU Locked Out on Faults.** This shows that the ECU has determined that too many faults of one kind have occurred and that the engine will not run on gas until the problem has been fixed. After the problem is remedied, use the ALT and HOME buttons on the status screen to acknowledge the fault.

**Long Pause in Process.** The ECU has determined that a longer period of time than usual is needed before re-attempting gas operation. Use the ALT and HOME buttons on the status screen to shortcut this wait if it is unnecessary.

**Pilot Stop Test Active.** When the ALT and the PG DN buttons on the status screen are simultaneously depressed, the pilot fuel rams will be activated if: (1) The engine is off gas and not running, (2) the MR/EN (enable) is off, and (3) the gas pressure is less than 25.0 psi

**Pilot Stop Test Canceled.** Occurs when one of the above conditions is not met.

**Replace Ether Canisters.** This indicates that there is less than 30 seconds of ether left in the canisters and that they should soon be replaced.

**Reset the Ether?** When the Ether canisters for the cold start system are replaced, the ECU should be informed that the canisters are full. This is done by simultaneously depressing the ALT and PG UP buttons on the status screen. To confirm the resetting, press the PG UP button.

**Attention - ECU's SBC-53 Battery Low.** This is a rare message indicating a low CPU battery that needs to be reported to ECI.

**Initializing ECU...** This message should appear on power-up. If it is seen repeatedly, it may indicate that the power to the ECU is inconsistent.

**Initialization Error.** This message indicates that the computer memory or hardware is faulty.

**ECU Hardware not responding. !Hardware Fault !** This message occurs when one of the peripheral computer cards is faulty.

## 5.4 The ECU

The ECU is a microprocessor-based controller that controls main engine parameters such as speed and GIV timing, monitors engine performance, and records and displays important operating data and engine diagnostic data required for maintenance purposes. The ECU is completely integrated with the existing ECP so that local controls on the ECP can be used as originally intended for local operation, or so that the ECU can be used for fully automatic operation, utilizing the monitoring and control functions already available on the ECP and switchgear and adding to them, as required.

**5.4.1 ECU Status Screen.** Data from the ECU can be obtained on the ECU status screen (Figure 5-2) located near the ECP. Information such as exhaust temperatures, other system temperatures and pressures, and gas system fault conditions can be read from the status panel display. To reach the desired information screen, press the **PAGE UP/PAGE DOWN** buttons as necessary (Fig. 5-3). The panel can also be used to initiate other functions, such as air ram test cycles, by pressing certain combinations of buttons. (See the troubleshooting section and individual system maintenance sections below.)

Figure 5-3 shows, in order, the titles of screens that are available by using the **PAGE UP/PAGE DOWN** buttons. From these menu titles, specific information needed for the dual-fuel engine can be accessed. To access fault histories, scroll **PAGE DOWN** through the items listed. To skip fault histories, scroll **PAGE DOWN** through the items listed, or use the **PAGE UP** button. Other button sequences for control of the status screen are as follows:

**ALT + PG DN = Rack Stop Test**

**ALT + HOME = Acknowledges an Alarm**

**ALT + PG UP = Ether reset (new ether canisters have been installed)**

The **HOME** button will return the screen to **ECI, ALL VALUES** unless a fault exists, then **HOME** will take you to **FAULT/CONDITION**.

**5.4.2 Computer Interface.** The ECU can be connected to an IBM compatible computer through its serial communication port. The computer (a laptop for example) can display more information at one time than is available on the status screen. The computer may also be used for retrieving data files that the ECU has recorded.

The ECU may have its operational parameters adjusted through the serial port by making changes to one of its control files and loading the new code. The door of the ECU must be opened in order to gain access to the serial port connector on the SBC V53 control board. ECI's software must be used to communicate with the ECU. Table 5-2 provides guidance for using a laptop computer to communicate with the ECU.

**5.4.3 Using LCD Screen Editor.** Simple changes/adjustments in the files **CONTROL.TXT** (which stores values of operating parameters for the ECU, Table 5-3) and **ALARM.TXT** (which stores parameter values for alarm settings) can be modified without the use

of a laptop by using the LCD screen buttons (Note: To effectively use this editor the user needs to be trained by the supplier of the ECU (ECI) to ensure a full understanding of the effects of the changes being made.)

This editor can only be used when the unit is not running on gas and when ECU functions are not otherwise needed. The following steps apply.

1. After starting the editor the screen will display a list of \*.TXT.
2. Move through the files with the **UP/DOWN** buttons and select a file with the **HOME** button to get into the edit mode.
3. Edit mode controls:

- **UP** and **DOWN** buttons move up and down through file
- **DOWN/HOME** together to move right
- **UP/HOME** together to move left

**UP and DOWN** together- toggles between moving through the file and character change mode (large blinking cursor).

When in character change mode, **UP** and **DOWN** buttons change the character at the cursor.

- **ALT** button to exit and save
4. When finished, the ECU will automatically reset and run the control program.
  5. If left unattended for several minutes the editor will stop and the ECU program will start automatically.

**5.4.4 ECU Dial-Up Software.** Table 5-4 describes the hardware requirements, computer set-up, the files used, and the control keys for accessing the ECU from a remote location. Figure 5-4 shows one of the screens available as graphic output at the remote location along with the nomenclature that applies to the entries on this screen.

**5.4.5 Static Protection Precautions.** Generally, the ECU chassis should not be opened unnecessarily. If a troubleshooting procedure requires work to be done inside the ECU, static electricity protection procedures must be followed. The following points should be observed when working inside the ECU or handling circuit boards:

- Turn off the system power before any connectors or boards are removed or installed.

- Put on a static grounding wrist strap such as 3M model 2210 before installing circuit boards or checking internal ECU connections. Wrap the Velcro strap around one wrist and clip the lead to the metal chassis of the ECU. Be sure the lead stays clipped to the chassis during the work.
- Do not remove circuit boards from static protective packaging until just before installation.
- Place replaced circuit boards in static protective packaging and return to ECI.

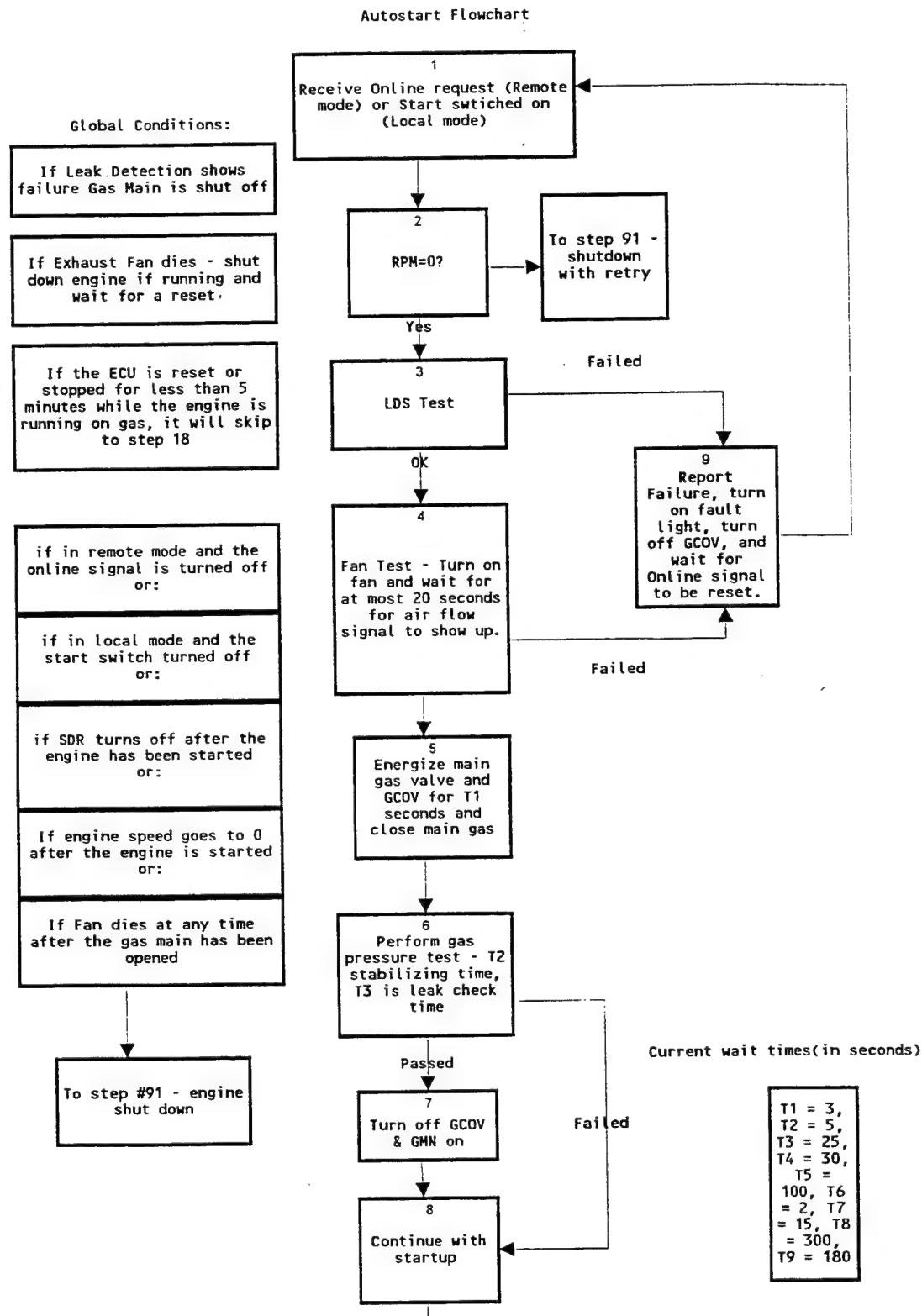


Figure 5-1. Autostart flowchart.  
(Used by permission, Energy Conversion, Inc., U.S.A., 1996.)



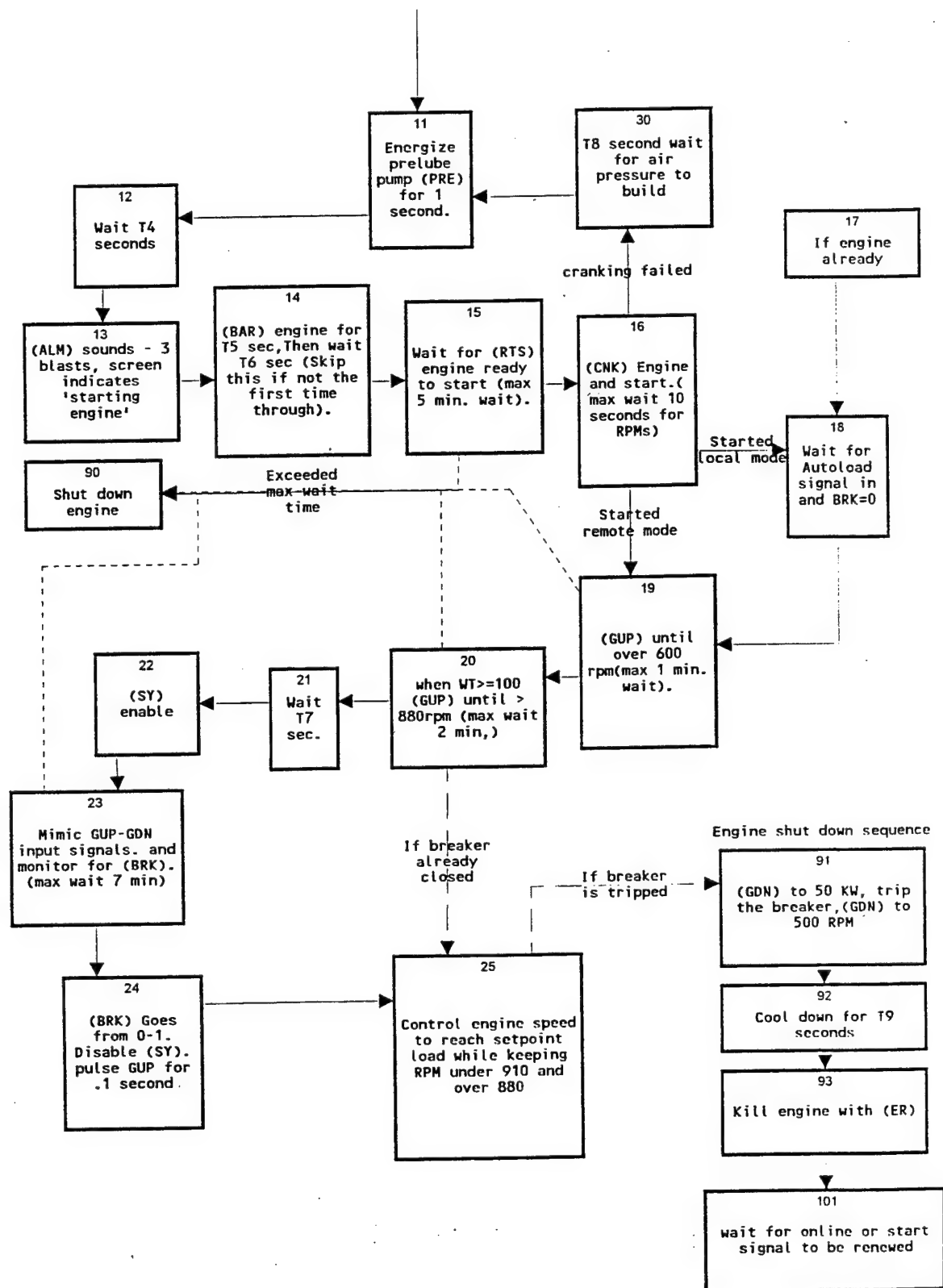


Figure 5-1. Autostart flowchart. (Cont'd.)

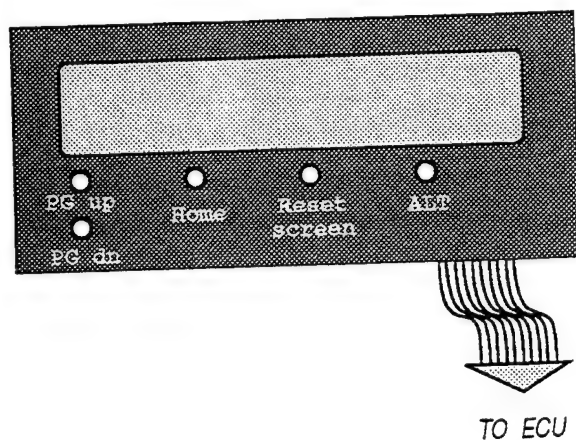


Figure 5-2. ECU status screen.  
(Used by permission, Energy Conversion, Inc., U.S.A., 1996.)

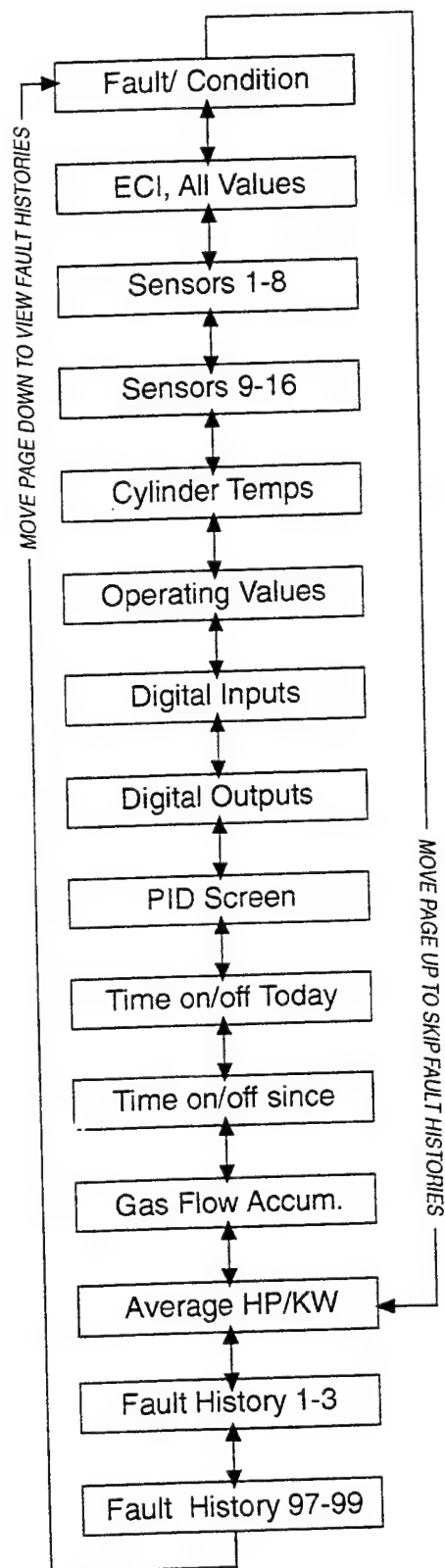


Figure 5-3. ECU status screen page sequence.  
(Used by permission, Energy Conversion, Inc., U.S.A., 1996.)

In the View program the keys:

- F1 - show the analog sensors in the bottom window
- F2 - show the average screen in the bottom window L - toggle logging on/off - this will record the data into the file ECU.LOG
- [ESC] - quit the program
- [Space] - while in playback mode, to step through a log file

the View screen

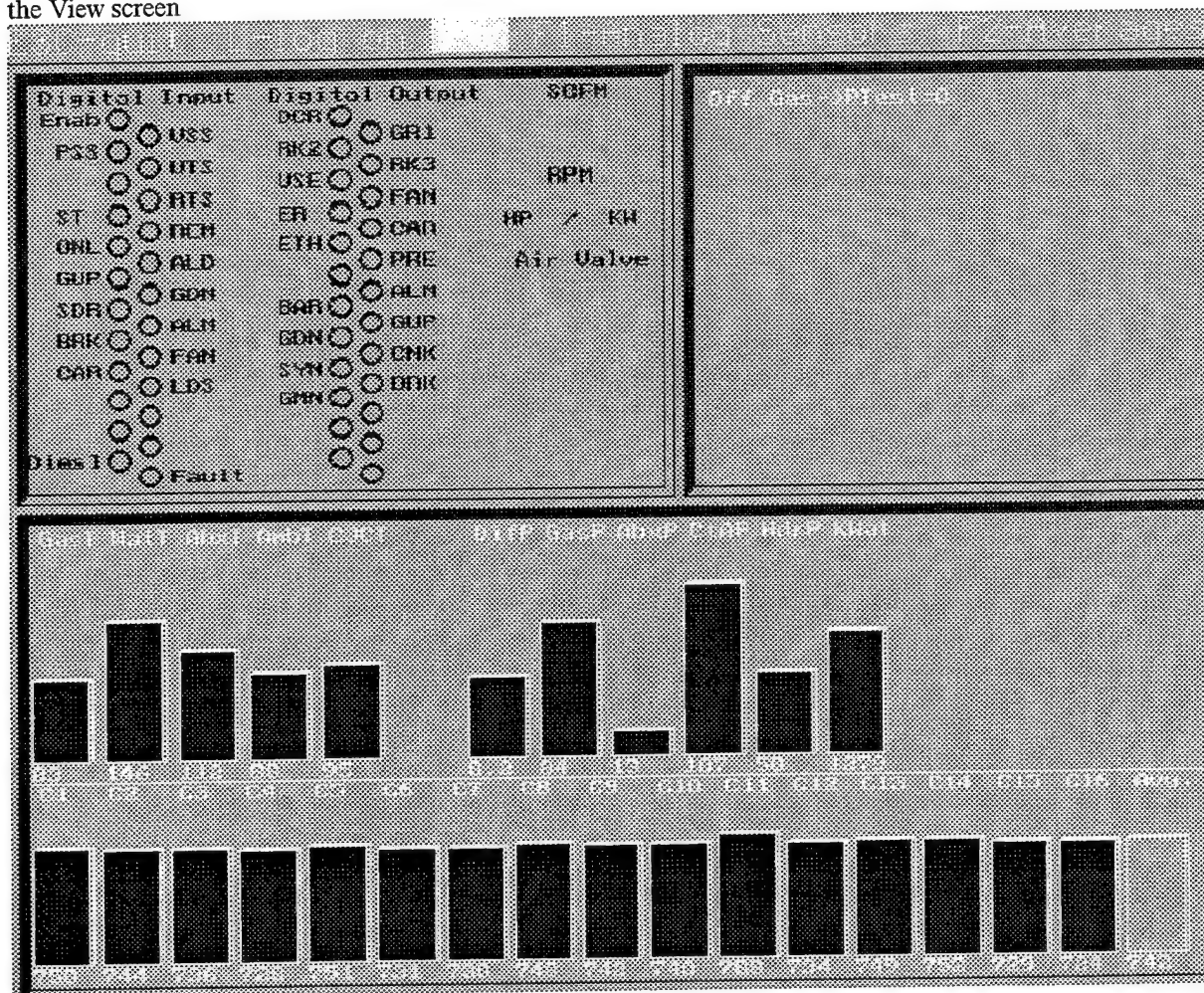


Figure 5-4. Screen one of remote computer readout.

## Description of the screen elements:

### Digital Inputs Bits:

Enab - Gas run enable switch - needs to be on for gas operation  
VSS - Valve sequencer status - will be on when running on gas  
PSS - Power Supply Status - turns off if the power supply is faulty  
VTS - Valve Temperature Switch - trips off if a gas valve overheats  
RTS - Ready To Start - turns on after baring engine  
ST - Start - momentary start button  
REM - Remote/Local switch - turns on when in remote, off in local  
ONL - Online request - requests engine to be online while in remote mode  
ALD - Autoload - ECU will autoload engine in local mode if up  
GUP - Governor Up signal  
GDN - Governor Down signal  
SDR - Shut Down Relay - turns off to shut down engine  
ALM - Engine Alarm signal  
BRK - Breaker - turns on when synchronizer closes the breaker  
FAN - turns on when fan runs  
CA - Cold Air Relay - turns on when cold air system is on  
LDS - Leak Detection System - turns off if a gas leak is detected  
CON - Condition - a condition has occurred that prevents gas operation  
FLT - Fault - a fault has occurred that prevents gas operation

### Digital Output Bits:

DCR - Diesel Control Ram - when on this energizes the Diesel Control Ram  
GR1 - Gas run 1 - enables gas to flow to the gas injectors  
RK2 - Rack Stop #2 enable  
RK3 - Rack Stop #3 enable  
VSE - Valve Sequencer Enable - ECU turns this on to enable the valve sequencer  
FAN - Fan enable - starts the ventilation fan  
ER - Engine Shutdown - picks up the ER relay on generator  
CAR - Cold Air Relay enable  
ETH - Ether Injection - injects ether into engine during startup  
PRE - Prelube - starts the prelube pump  
ALM - Alarm - echoes the ALM input and sounds a start-up warning horn  
BAR - Bar engine during autostart  
GUP - Governor up - echoes the GUP input during autostart  
GDN - Governor down - echoes the GDN input during autostart  
CNK - Crank engine - energizes the starter  
SYN - Synchronizer enable - enables synchronizer during autostart  
BRK - Trip Breaker -  
GMN - Gas Main - when on, this opens the main gas valve outside the generator compartment

SCFM - gas flow in Standard Cubic Feet Per Minute

RPM - engine speed

HP/KW - horsepower & kilowatts

Air Valve - position of the air throttle valve

GasT - Gas Temperature

WatT - Jacket Water Temperature

AbxT - Air Box Temperature

AmbT - Ambient Temperature

CJCT - Cold junction compensation temp. for thermocouples

DiffP - Gas Differential Pressure

GasP - Gas Supply Pressure

AbxP - Air Box Pressure

CtAP - Control Air Pressure for gas valves

HdrP - Gas Header Pressure

Kwatt - Kilowatts

C1-C16 - Exhaust Temperatures for each cylinder

Avg - average exhaust temperature

The upper right hand window shows the on/off gas status along with other important occurrences.

Figure 5-4. Screen one of remote computer readout. (Continued)

Table 5-1. Alarm Setting Criteria

Name	Description	gas operation affected	low limit	low alarm clear	high alarm clear	high limit	time off after clear	# faults before long pause	long pause time	max # pauses before lockout
WT	water temperature	Yes	145F	160F	195F	200F	10 Sec.	10 in 4hr	4hrs.	1
GT	gas temperature.	Yes	5F	22F	100F	170F	10 Sec.	10 in 2hr	1hr	1
ABxT	air box temp.	Yes	84F	95F	185F	210F	10 Sec.	10 in 2hr	2hrs	1
AmbT	ambient air temp.	No	n/a	n/a	120F	125F	n/a	n/a	n/a	n/a
CJCT	cold junction temperature	No	n/a	n/a	120F	180F	n/a	n/a	n/a	n/a
GasP	gas pressure	Yes	70psi	80psi	110psi	115psi	10 Sec.	15 in 2hr	4hrs	1
CtAP	control air pressures.	Yes	115psi	123psi	138psi	147psi	10 Sec.	15 in 2hr	2hr	1
HdrP	header pipe prs	Yes	n/a		20psi	75psi	20 Sec	10 in 2hr	1hr	2
DiffP	differential pressures	Yes	n/a		30psi	32psi	30 Sec	5 in 2hr	1hr	2
AbxP	air box pressure	Yes	n/a		19psi	22psi	20 Sec	10 in 2hr	1hr	2
RPM	engine speed	Yes	770rpm	880rpm	915rpm	925rpm	10 Sec	5 in 2hr	2hrs	10
KW	Killowatts	Yes	300		1650	1700	20 Sec.	10 in 2hrs	1hr	2
AFMix	air/fuel mix ratio	Yes	n/a		3.8:1	6.5:1	1 Sec	15 in 2 hr	2 hrs	15
Ptest	autostart pressure test	Yes	must pass test during autostart							
ExhAv	average exhaust temp	Yes	250F	300F	1200F	1250F	10 Sec	15 in 2hr	1 hr	2
MR/EN	gas enable	Yes	signal must be on				1 Sec.	n/a	n/a	n/a
Fan	ventilation fan	Yes	fan must stay on				30 Sec.	10 in 2hrs	2 hrs	1
Vseq	valve sequencer	Yes	signal must stay on when running on gas				10 Sec.	5 in 2hrs	2 hrs	2
LDS	leak detection system	Yes	a leak is indicated if the signal is off				10 Sec.	1 in 1min	1min	2
CA	cold air feedback	Yes	must stay up if cold air relay is energized				5 Sec.	5 in 2 hrs	2hrs	2
PowS	power supply status	Yes	power supply is faulty if signal is off				5 Sec.	2 in 2hrs	2hrs	1
ALM	gen. set alarm signal	Yes	engine alarm indicated when signal is on				0 Sec.	0	n/a	n/a
SDR	shut down relay	Yes	when signal is off, the engine is shutting down				1 Sec	10 in 2hrs	2hrs	1
VTs	valve temperature switch	Yes	when the signal is off, a valve has overheated, if in 90 seconds the signal doesn't turn on the engine will shut down				20 Sec	50 in 2hrs	2hrs	2

Table 5-2. Laptop Communications with the ECU

**1) Connecting to the ECU**

To communicate with the ECU use a null-modem cable connected to the serial port (Com1 or Com2) of your laptop or PC. The other end is connected to the SBC53 rack card's connector J1 inside the ECU.

**2) Establishing communications with COMM.EXE**

First, go to the directory in which COMM.EXE resides (probably C:\WS). If you are hooked to Com1 then type `COMM[ENTER]`. If you are hooked to Com2 type `COMM /Com2`. The ECU communicates at 2400 Baud. Check the baud rate at the bottom of the screen to see if COMM is also communicating at 2400 Baud. If not, press `[ALT+B]` successively to change the baud rate to 2400.

To stop the ECU from running control code and to get into DOS, press `[ESC]`. You should see the DOS prompt `B:\`

You may now use many familiar DOS commands such as `DIR, REN, COPY, TYPE.....`

To exit COMM, press `[ALT+X]`

**3) File Transfers**

To transfer a file from the laptop to the ECU type (from the B: drive):

1) `TRANSFER {filename} [ENTER]`

2) `[PAGE UP]` - COMM will now prompt for a file name

3) type in the filename to transfer and `[ENTER]`

4) select X for the XMODEM transfer protocol

the file will now transfer to the ECU - a string of `TTTTT...` will appear

To transfer a file from the ECU to the laptop type (from the B: drive):

1) `TRANSFER -S {filename} [ENTER]`

2) `[PAGE DOWN]` - COMM will now prompt for a filename

3) type in the filename to transfer and `[ENTER]`

4) select X for the XMODEM transfer protocol

the file will now transfer to the laptop - a string of `RRRRR...` will appear

**4) Changing to a higher baud rate for faster transfers**

For large files, 2400 Baud can be slow. To speed up the baud rate use `BRC.EXE`. Type `BRC`

`7 [ENTER]` - this will change the baud rate to 57600. Now press `[ALT+B]` until 57600 appears at the bottom of the screen and press `[ENTER]` to get the DOS prompt back at the higher speed.

\* Note - when you start the control code running again the baud rate will revert back to 2400 baud automatically

**5) Files on the ECU and what they do:**

`ECU.BAT` - start-up and contains the control code

`ECUPROG.EXE` - the main control code file

`ALARM.TXT` - holds gas system alarms

`CONTROL.TXT` - holds data prescribing options for the code

`JAN95.PRF` - a daily performance file (gas use, KW hours, etc.)

`BITTEST.COM` - utility to turn on & off selected bits (type `BITTEST` for options)

`PWMTEST.COM` - utility to test the pulse width output (type `PWMTEST` for options)

Table 5-3. Listing of Computer File CONTROL.TXT  
Which Provides Reference Data for ECU

CYLINDERS (8,12,16,or 20)

16

; Gas On & Off Sequence - timed sequence in 100th of seconds

; gas valves are time 0 - others are timed after valves

; DieselControl/TNRelay Bit, GR/R1, R2&3

ON SEQUENCE

50 10 10

OFF SEQUENCE - same as above, expressed as 100ths of a second before valves turned off

20 30 30

; Rack Stops- value 1 is low threshold, value 2 is high threshold,

; S indicates RPMx10, H indicates Horsepower control

RACKS - Rack 2, Rack 3

500 540 H

4000 6000 S

; Cold Air Relay - if any of these (hp,gt,wt,abt[throttle]) go below their limit

; CAR will switch to 'switch value'

COLD AIR RELAY - On/Off switch\_val Pacesetter\_on/off HP GT WT ABT[0-8]

1 0 0 1000 0 12000 1700 1700 1700 1700 1700 1700 1700 1700 1700

; LEI

; engine needs to run over 'EngineRunning' RPMx10 for 20 seconds to run lei

; can also enable/disable pacesetter and noload modes of LEI

LEI - on/off EngineRunning pacesetter(1/0 = y/n) NoLoad(1/0 = y/n)

0 2000 1 1

; Fans - successive # of fans & hot engine signal are turned on as wt goes above each point

; Fan1 (tn 0 - 8),Fan2 (tn 0 - 8),Fan3 (tn 0 - 8),HotEngine value

FAN CONTROL - on/off

0

1900 1900 1900 1800 1800 1800 1800 1750 1750

2000 2000 2000 1900 1850 1850 1850 1800 1800

2050 2050 2050 2000 1900 1900 1900 1850 1850

2120

; Pid

PID - speed active, air active, excitation active

0 1 0

; DownRate Cutlimit Stepsize Delay AfterTransitionResetNotch

500 6000 20 1 4

; setpoints[0-8], reset[0-8,Air,Exc], P[0-8,AirP,ExcP], I[0-8,AirI,ExcI], D[0-8,AirD,ExcD]

00 3100 3900 5000 5700 6650 7380 8320 9020 2130 0

0 5000 7500 12500 13500 15000 17500 18500 20000 19000 5000

500 25 180 180 180 180 180 180 180 500 100

30 30 50 60 50 50 50 50 50 500 100

950 40 170 190 175 150 140 140 140 25 10



Table 5-3. Listing of Computer File CONTROL.TXT  
Which Provides Reference Data for ECU (Continued)

AIR THROTTLE prs setpts for 0% 25% 50% 75% 100% of max hp (10th pid stpt), 0% & 100% pulse width numbers

80 100 120 130 160 5200 7200

; Cold Start

COLD START - On/Off, Start Delay(100th of sec), Min Crank RPMx10, Max Crank RPMx10,

Hysteresisx10,

; Cut Out RPMx10, (ML of Ether/sec)x10, (MLx10 in a full can)

1 100 250 6000 2000 200 25 8330

PRESSURE SCALE

;full scale for channel 6,7,8,9,10,11(KWatt on gen set),12,13,14,15

35 250 30 250 250 2500 1 500 20 20

IDLE CONTROL

0

THROTTLE NOTCH

0

DIESEL CLEANOUT

0

KVA INPUT

1

ORS TIME

0

THERMOCOUPLE

J

KIT VERSION 0-Navy 1-Sundowner 2-Locy ... add more later

0

CALLBACK

ATDT 99222258

DIGITAL LABELS

EN ,VSS,PSS,VTS,---,RTS,ST ,REM,ONL,ALD,GUP,GDN,SDR,ALM,BRK,FAN,CAR,LDS,---,---,---,---

,---,---

DCR,GR1,RK2,RK3,VSE,FAN,ER

,CAR,ETH,PRE,CON,FLT,BAR,GUP,GDN,CNK,SYN,BRK,GMN,ALM,---,---,---,---

AUTOSTART

; on/off, load\_setpoint(x10), load\_maximum(x10),

; times1-10(energize,stabilize,leak check,prelube,bar,afterbar,before synch,retry crank,cool down,spare

; time 1 2 3 4 5 6 7 8 9

;1 15000 times found in chart t1-t9

1 15000 17250 3 5 25 30 100 2 15 300 180

Table 5-4. Accessing the ECU From a Remote Location

(A) Hardware requirements:

IBM 386 or higher PC  
2400 baud modem  
VGA video capability

(B) Setup: from the floppy drive type **install** <ret> and follow instructions when asked for com port and phone number. The following files need to be installed on the c: drive: callecuc.bat, viewcu.bat, dialup.exe, hangup.exe, and view.exe.

(C) File functions:

CALLECU.BAT - dials the ECU and starts the VIEW.EXE program  
VIEW {filename} - replays a previously recorded log file (e.g. VIEW ECU.LOG)  
VIEW [/Com1][/Com2] - will start the view program when a laptop is connected to the ECU via a null modem cable. The null modem cable needs to be connected to the SBC-V53 board in the ECU. Disconnect the serial cable from the 2401 modem card and connect the null modem cable to the 9-pin connector at the end of the ribbon cable. When finished using the laptop, reconnect the ribbon cable to the 2401 modem card.

(D) Within the VIEW program use the following keys:

**F1** - to show the analog sensors in the bottom window (Figure 5-4)  
**F2** - show the average screen in the bottom window  
**L** - toggle logging on/off - this will record the data into the file ECU.LOG  
**ESC** - quit the program  
**Space** - while in playback mode, to step through a log file

## **6.0 FIELD SITE INSTALLATION, MAINTENANCE, AND TRAINING**

### **6.1 Site Requirements**

Site requirements for installation and operation of the 1,500 kW dual fuel diesel generator set are identical, with two exceptions, with those required for the unmodified diesel units. Those two exceptions are: (a) the requirements for a natural gas supply, and (b) a capability to communicate electronically with remote sites for the purposes of both control and for data transmission. The site drawing for installation of the 1,500 kW unit at SUBASE King's Bay GA is shown on Figures 6-1 and 6-2. The unit is located across a roadway from an existing boiler plant, and the engine house and the switchgear house are each located on separate concrete pads. Trenching was provided to the unit for running (a) the natural gas supply line, and (b) the diesel fuel supply line along with a 4-inch electrical conduit for electrical power transmission cables and a 1-inch conduit for communication lines.

### **6.2 Maintenance Schedule and Procedures**

Maintenance procedures for the engine generator set for subjects other than those directly connected to the dual fuel conversion are the same as those for which standard maintenance procedures are already available (Ref 6-1). Several of the subjects dealing specifically with the dual fuel conversion are discussed in Appendix C. More detailed information is available in Reference 4-2. A recommended schedule for periodic maintenance activities is provided in Table 6-1. The subjects addressed in the appendix are special tools, injector calibration, injector settings and adjustments, a recommended spare parts list, and a trouble-shooting guide.

### **6.3 Training**

Training is required in the areas of both maintenance and operation. A major step in this direction was taken by the decision to use MUSE personnel for installation of the dual fuel system on the MUSE unit and for its start-up. This established a hands-on familiarity within MUSE of the complexities of the installation and of the operational features of the dual fuel system. In the process of the installation of this system and its subsequent start-up, the adequacy of the suppliers publications (Refs 4-1, 4-2, and 4-3) for describing installation, operating and maintenance procedures was demonstrated. Therefore those documents provide not only the basic technical knowledge of the dual fuel conversion, but with supplementary knowledge provided by ECI bulletins and by this document, the background needed for personnel to understand the conversion is provided. In addition, as this dual fuel conversion is now being implemented by other commercial users, a one and one-half hour training video (Ref 6-2) prepared by ECI, is now available.



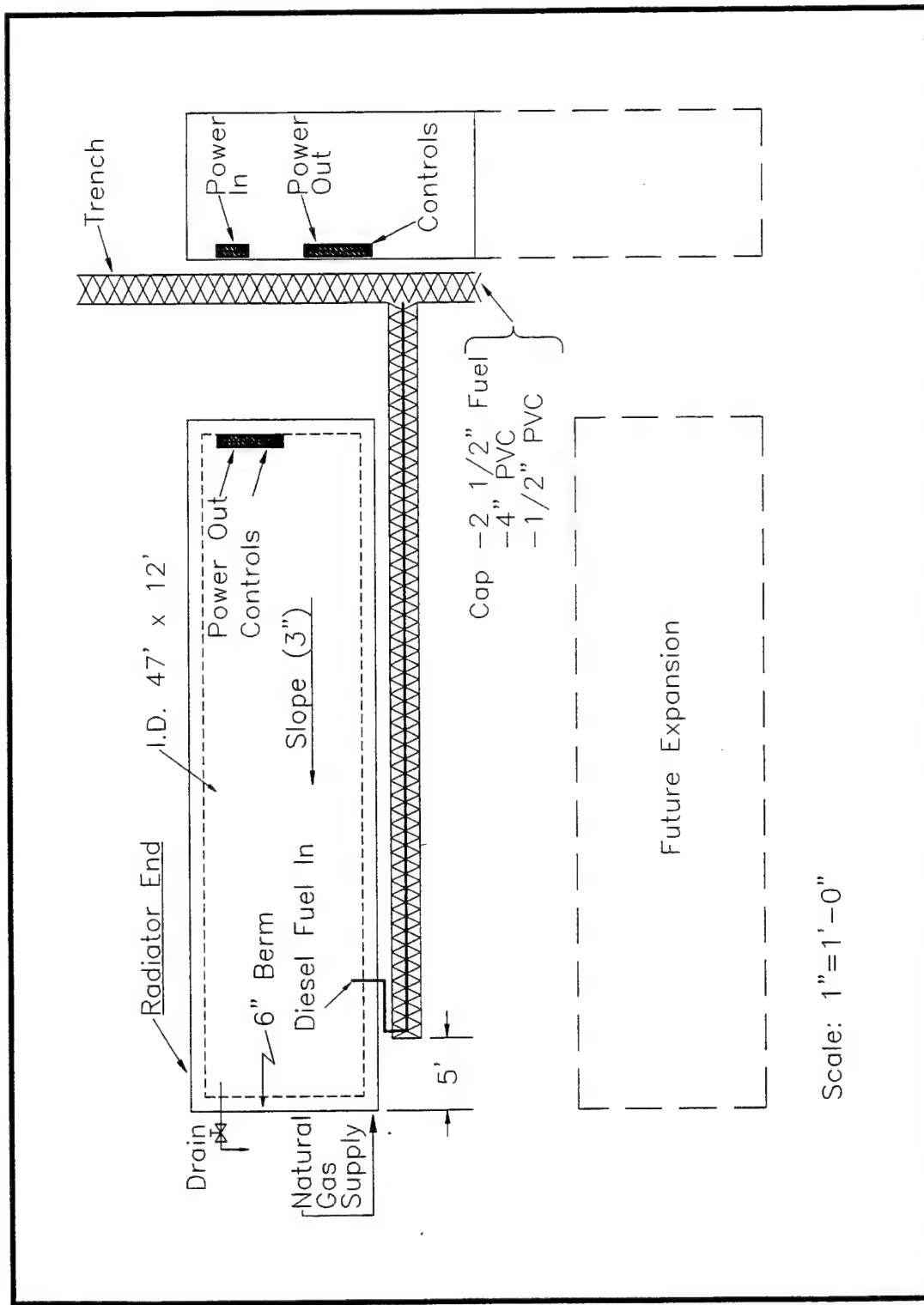


Figure 6-2. Schematic diagram of concrete supporting slabs showing functional requirements.

Table 6-1. Recommended Maintenance Schedule

<u>Inspections</u>	<u>Frequency</u>
Verify gas operation	Daily
Observe gas hours of operation and log entries of faults experienced. (Available on ECU information screen or by remote phone link.)	Daily
Aftercooler pump	Weekly
Inspect operation	Quarterly
Lube	
GIV oiler service	Weekly
Test gas quality	Monthly (Weekly for first six months)
Record gas filter differential pressure	Monthly
Inspect gas supply line and pipe fittings for leaks	Monthly
Inspect gas system leak detection system	Monthly
Gas flow control valve (Spray-lube the linkage swivel joint between governor arm and gas flow control valve arm in two places. Use LPS3 or a similar lubricant.)	Monthly
Leak detection system sensor inspection and calibration*	Semi-annually
Inspect/calibrate exhaust thermocouples	Annually
Inspect/calibrate all other sensors	Semi-annually
Lubricate ECU fan	Annually

Table 6-1. Recommended Maintenance Schedule (Continued)

<u>Parts Replacement</u>	<u>Frequency</u>
Gas Flow control valve* (Disassemble valve and replace O-rings and seals when engine is rebuilt or if it is leaking.)	5-7 years
Change GIV actuation seals	8,000 hours of operation
Gas cutoff valve (replace O-ring seals)	5 years
Control air regulator	5 years
GIV gas lines (internal on engine)	5 years
Gas inlet valve (GIV) (unit exchange)	5 years
Aftercooler coolant pump (rebuild)	5 years
Heat exchanger zinc anodes	5 years

\* Gas Flow Control Valve should not require maintenance on internal parts unless gas filter is not serviced properly. The valve must be kept clean and free of internal debris to function properly.



## 7.0 CAPITAL AND OPERATING COSTS OF THE DUAL-FUEL MUSE GENERATOR

The capital requirements for conversion of MUSE engine generator sets to dual fuel operation consist of hardware costs, installation costs, and the costs for an inventory of spare parts. These are summarized in Table 7-1. Hardware costs are, largely, covered by the cost of the dual fuel conversion kit provided by the supplier. This kit has been developed, specifically, for generator sets using the EMD 645 engine, and most hardware items that will be needed for the conversion are included. The exceptions, in the present case, are caused by requirements that result from the special 'packaging' of the MUSE engine generator sets into mobile units required by the Navy. These special requirements, and their impact on the system hardware costs, are identified in the table. The costs for installation (labor) are estimates based both on the labor involved in the conversion of this MUSE unit and on the conversion of subsequent commercial units.

The cost per kilowatt of power for the dual fuel conversion is a function of the size of the unit converted and of the fraction of the rated horsepower at which the engine is operated. The data in Table 7-2 provide estimates of this cost for retrofitting existing MUSE diesel generators for dual fuel operation, the cost additive for including a secondary chamber ignition system in the dual fuel system, and the cost of replacing the MUSE diesel generators with new, spark-ignited, gas-fired engine generator sets.

It is anticipated that the operating costs for dual fuel MUSE generating sets will be substantially less than those for diesel operating units. These savings are due, primarily, to anticipated fuel savings, but also due to some labor savings as a result of the automation of the operation of the units. Operational added costs would result from the requirement of maintaining some additional hardware. These costs are summarized in Table 7-3.

Table 7-1. Capital Costs for Converting of Navy MUSE  
Generating Sets to Dual Fuel Operation

	16 Cylinder (1,500 kW) (K\$)	20 Cylinder (2,500 kW) (K\$)
Hardware costs		
ECI dual fuel kit*	225	250
Supplementary hardware costs for MUSE units*	12	14
Installation and startup (labor, services)†	45	55
Totals	282	319
Cost/kW‡	188	128

\*ECI's dual fuel conversion kit has been assembled to provide essentially all hardware components required for this conversion. This includes preassembled wiring harnesses ready to be drawn through conduits and connected to their terminals. However, the kits do not include hardware items that are unique to the MUSE application. The latter include a larger air compressor and other miscellaneous hardware.

†Installation and startup include 700 to 900 hours of labor plus other services.

‡The cost effectiveness of converting 2,500 kW units is significantly improved both because the engine in the 2,500 kW application is required to work at a level much closer to its rated horsepower and because the costs are common to the units and of the same amount.

Table 7-2. Estimated Costs for Four Approaches to Achieving Lo-NO<sub>x</sub>  
Muse Engine Generator Sets

Approach	Estimated Total Cost (K\$)	Estimated Cost/kW (\$)
I EMD 645 dual fuel conversion (16 cylinder - 1,500 kW)	282	188
II EMD 645 dual fuel conversion (20 cylinder - 2,500 kW)	319	128
III EMD 645 dual fuel conversion with secondary ignition chamber* (20 cylinder - 2,500 kW)	379	152
IV New spark-ignited natural gas engine† (1,200 kW)	425	354

\*Based on estimated costs for a secondary ignition system for the EMD 645 engine as discussed in Section 2.0.

†Based on cost of new engines available on the market installed in the required Navy MUSE configuration.

Table 7-3. Estimated Operating Costs of Navy MUSE Generating Sets (2,500 kW)  
for Diesel and for Dual Fuel Operation

	Diesel Fuel (K\$)	Natural Gas (K\$)
Fuel cost/1,000 hrs. operation*	210	92
Operating labor (daily start/stop)†	8	1
Maintenance adder for natural gas	5	10
Totals/1,000 hrs. of operation	223	103
Totals/1,000 hrs. of operation	282	319
Energy cost (cents/kW-hr)	8.9	4.1

\*Fuel costs were calculated based on those applicable for the dual fuel unit installed at SUBASE King's Bay, GA. For that installation, the equivalent cost per therm (100,000 Btu's) was .33/therm for natural gas (including a 10% penalty for loss in efficiency for natural gas firing) and .75/therm for diesel fuel.

†An operational cycle of 10 hrs/day of operation for 100 days was assumed. A labor rate of \$40.00/hr was assumed.

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6-2. *Energy Conversions, Inc., Training Video*, June 1996.

## 9.0 GLOSSARY

The following abbreviations have been used to describe major components of the dual fuel conversion system:

<u>Abbreviation</u>	<u>Definition</u>
ASC	Air service cabinet
BDC	Bottom dead center
BTu	British thermal unit
DF	Dual Fuel
DP	Differential pressure
ECI	Energy Conversions, Inc.
ECP	Engine control panel
ECU	Electronic control unit
EI	Early injection
EMD	Electro-Motive Division of General Motors Corporation
FRL	Filter/regulator/lubricator
GCOV	Gas cutoff valve
GFCV	Gas flow control valve
GIV	Gas injection valve
gm/HpH	grams per horsepower-hour
LCI	Late-cycle injection
LDS	Leak detection system
LEI	Low emission idle
LEL	Lower explosion limit
LNG	Liquefied natural gas
MUSE	The Navy's mobile utilities support equipment
NG	Natural gas
NO <sub>x</sub>	Nitrogen oxides (nitric (NO) and nitrogen dioxide (NO <sub>2</sub> ))
RPM	Revolution per minute
SCAQMD	South Coast Air Quality Management District
SCF	Standard cubic foot
SCFM	Standard cubic foot per minute
SCR	Selective catalytic reduction

<u>Abbreviation</u>	<u>Definition</u>
SG	Switchgear
SGP	Switchgear panels
SNCR	Selective non-catalytic reduction
SwRI	Southwest Research Institute
TDC	Top dead center
VTs	Valve temperature switch

**Appendix A**

**LETTER REPORT REGARDING FIRE SAFETY MEASURES FOR  
CONVERSION OF USN MUSE DIESEL-GENERATOR UNITS FROM DIESEL  
TO NATURAL GAS FUELING**





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THOMAS W. JAEGER, PE, *President*

JOHN E. WOYCHEESE, PE, *Principal*

July 12, 1994

Mr. Norman Helgeson  
Mechanical Engineer  
Energy and Environment Department  
Naval Civil Engineering Laboratory  
Port Hueneme, CA 93043

Subject: Letter/Report Regarding Fire Safety Measures for Conversion of USN MUSE  
Diesel-Generator Units from Diesel to Natural Gas Fueling

Dear Mr. Helgeson:

The report given below examines the measures necessary to provide a reasonable level of fire safety in portable diesel engine driven diesel-generator units to allow for the addition of natural gas fuel capability. The suggestions given are conceptual in nature and do not constitute a detailed design documents such as would be necessary for equipment installation.

Introduction

The Navy is currently employing several diesel-generator units for mobile and emergency power uses. The skid-mounted units are to be converted from diesel to natural gas fuel to minimize exhaust emissions. This report contains findings and recommendations of a fire safety study. It analyzes measures needed to provide a reasonable level of safety against the hazard of fire or explosion due to the release and subsequent ignition of natural gas inside the diesel generator housing.

This study was requested by Mr. Norm Helgeson of the Naval Facilities Engineering Service Center (FESC). It was conducted under the direction of Jack Woycheese, P.E., Principal. Field work, evaluation and report writing was conducted by Ralph Kerwin, P.E., Senior Engineer. A field walkdown was conducted on July 7, 1994. Attending the walkdown were Mr. Helgeson, Master Chief Petty Officer Ron Kluender, Chief Petty Officer Jim Riley, Mr. Rand Drake, PO-1 Al Willey and PO-1 John Love. Gage-Babcock and Associates gratefully acknowledges the assistance of the above personnel and Mr. Scott Jensen of ECI in providing technical information used for this assessment.

Summary of Recommendations

Based on a review of drawings and technical information, together with field observation, Gage-Babcock and Associates concludes that electrical classification of the D-G enclosure is not required, providing that the following measures are observed:

1. Provide welded or threaded gas supply piping. The use of flanged or bolted fittings should be minimized (and eliminated if feasible). All piping, fittings and valves should be rated for a minimum of 150 psi. Bubble test joints under full design pressure.
2. Provide a supervised methane detector at ceiling level above the engine (see Attachment 1 for suggested location). The detector should be rated for the expected air flow rates in its suggested location.
3. Provide an independent air flow sensor for the fan to positively identify when the fan is operating. A dependable sensor without moving parts (such as a venturi-style device) is suggested for maintenance reasons.
4. Interlock the fan and the methane detectors to shut down the gas supply upon either of the following conditions:
  - a. Gas supply valve is open and fan is not running.
  - b. Methane is detected in a concentration greater than 1% by volume in air (this represents 20% of the lower flammable limit).
5. Provide a self-check sequence at startup. The ability to activate non-classified (spark producing) electrical equipment should be contingent on a clear reading from the gas detectors following verification of supply pipe pressure integrity (see Attachments 2 and 3).
6. Following engine stop signal and switchover to 100% diesel fuel operation, provide for automatic, momentary opening of the gas cutoff valve and gas vent valve to depressurize gas piping in the engine enclosure.
7. Institute procedures and practices to regulate the use of open flame operations within the engine enclosure during maintenance operations and to periodically evaluate tightness of any flanged or bolted gas pipe fittings.
8. Remove the two fan-coil heaters from the engine compartment. If these heaters cannot be removed, they must be interlocked to shut down (and cool down) prior to initiation of the pressurization test discussed in Item 5 above.
9. Ensure that adequate safeguards are present in the gas line to prevent a single failure (such as a regulator) from overpressurizing the gas supply line and associated equipment above 150 psig.

#### Description of D-G Unit

##### Enclosure:

An existing, typical diesel-generator unit is shown on Attachment 1. These units have a nominal output of 2300 KW. Each uses a GM Electro-motive Division Model 16-645 E4 engine, with 3070 hp. The engine sits in an enclosed compartment with interior dimensions of approximately 10 x 10 x 35 feet. A separate, adjacent compartment which contains the radiator is approximately 10 x 10 x 10 feet in enclosed dimension. Accounting for space occupied by equipment, the available space inside the engine compartment is approximately 2800 cubic feet. Ventilation within the engine compartment is provided by a 12,000 cubic

feet per minute (cfm) ceiling fan. At its rated flow, this fan provides four air changes per minute within the enclosure. The radiator compartment provides air-cooling for a radiator, and ventilation rates are extremely high. Three sides of the radiator enclosure are substantially open to the passage of air. Attachment 1 shows major equipment locations.

#### Proposed Conversion to Natural Gas:

The proposed conversion of the engine would allow for dual fuel operation, with an option for diesel piloted ignition of natural gas. The conversion would be conducted with equipment provided by a firm such as Energy Conversion Incorporated (ECI), which has converted other engines of this particular make and model for locomotive applications. Maximum natural gas flow to engine under normal operating conditions would be 350 scfm at 100 psig.

#### Hazard Analysis

The primary hazard which would exist due to conversion to natural gas would be leakage of gas from fittings in the gas supply piping inside the engine enclosure. Leaks could occur at flanged or screwed fittings, at the individual load blocks or at jumper hose fittings inside the engine cover. Sudden and catastrophic failure of a fitting is not anticipated unless caused by gross maintenance error. Such an error would be detectable through a gas detector following opening of the gas control valve during startup.

Natural gas is flammable in air at concentrations between 5% and 15% by volume. The primary criterion for not requiring electrical area classification in an enclosure containing pressurized gas piping would be that adequate ventilation be provided to ensure that a significant quantity of methane-air mixture could not accumulate in concentrations greater than 20%. Based on the fugitive emissions calculation method of NFPA 30, the existing ventilation rate is considered adequate to provide dilution for leaks of up to 150 scfm.

A worst case scenario would be an open 1-1/2 inch fitting connection (i.e. open pipe) due to maintenance error. Such a break would be detectable through a pressure integrity test (described below), which would involve a short period of gas pipe pressurization prior to engine start up. The purpose of the pressure test would be to discern piping leaks larger than could be handled by the ventilation fan (in excess of 150 scfm). If a worst case pipe disconnection were present in the gas piping, the primary restriction to flow would be the throttle valve, rated in its closed position at 40 lbs/minute. During and shortly after a five second release (the maximum recommended pressurization time period), the possibility of a flammable atmosphere would exist. During this time period, ignition sources could be controlled by operational means (not allowing exposed heating element operation, not allowing changes of state in sparking devices such as solenoids). The existing exhaust fan consists of an in-line squirrel cage induction motor which drives an aluminum propeller in an aluminum hub. This fan is inherently spark resistive and would be considered suitable for use to evacuate gas following such a substantial release.

Referenced Publications

1. NFPA 30, Flammable and Combustible Liquids Code, 1993 Edition, Appendix F, "Fugitive Emissions Calculations"
2. NFPA 70, National Electrical Code, 1993 Edition, Article 500, "Electrical Classification."
3. NFPA 497M, Manual for Classification of Gases ... for Electrical Equipment...., 1991 Edition.
4. AMCA Standard 99-0401-86, Classifications for Spark Resistant Construction.

If you have any questions, please call me at (510) 930-8000.

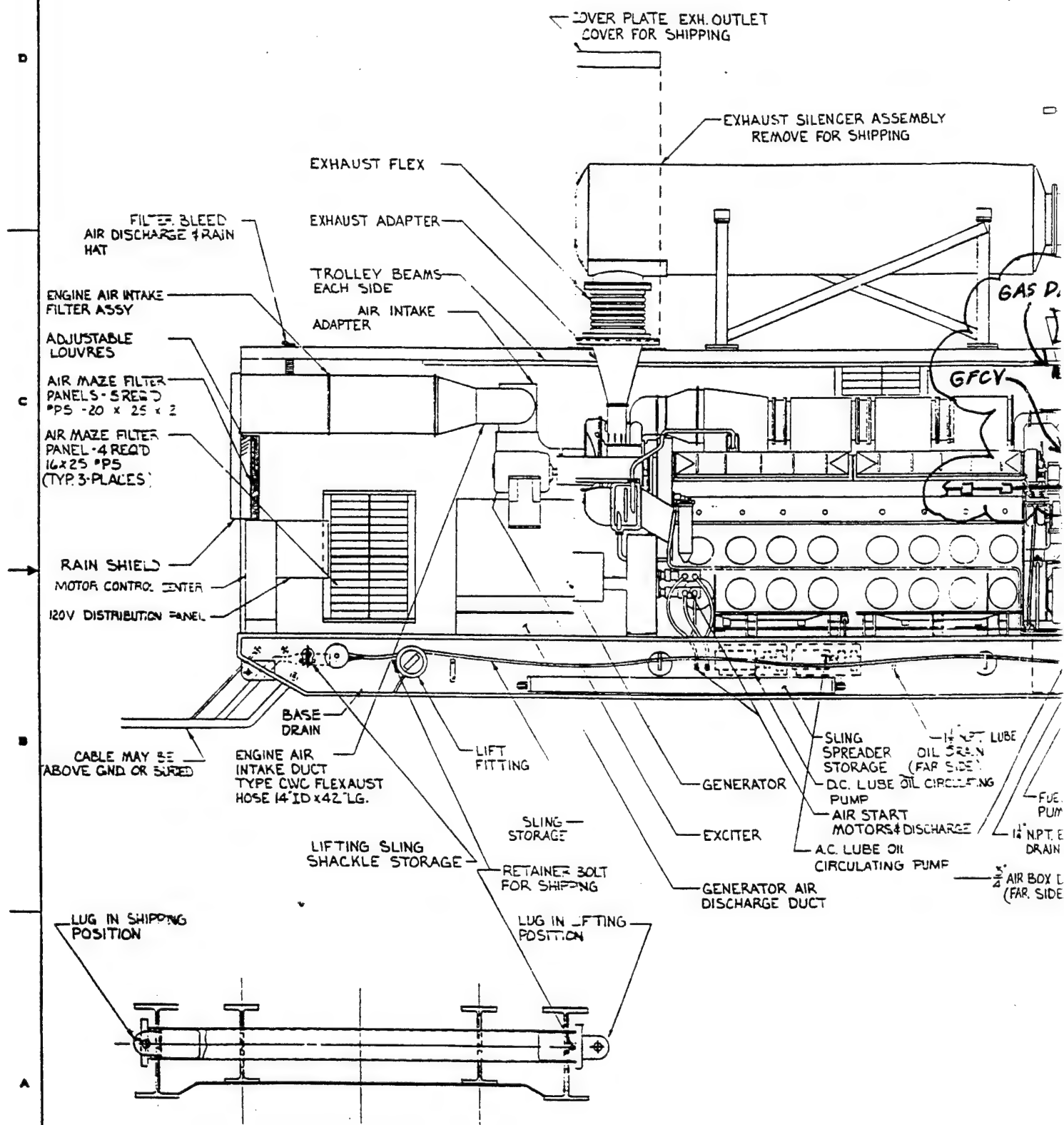
Yours sincerely,

Gage-Babcock & Associates

A handwritten signature in cursive script, reading "Ralph Kerwin".

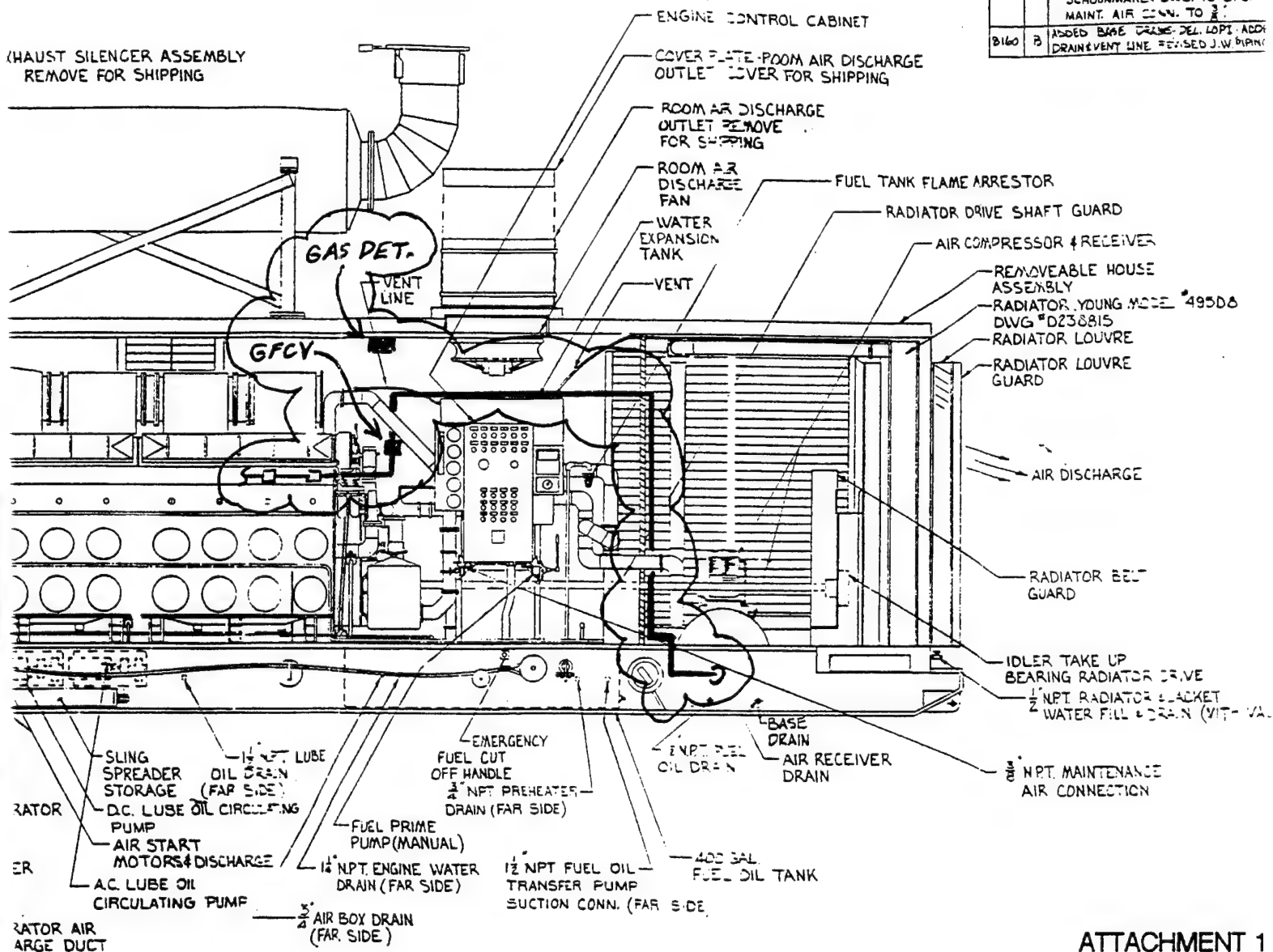
Ralph Kerwin, P.E.  
Senior Engineer

Encl.



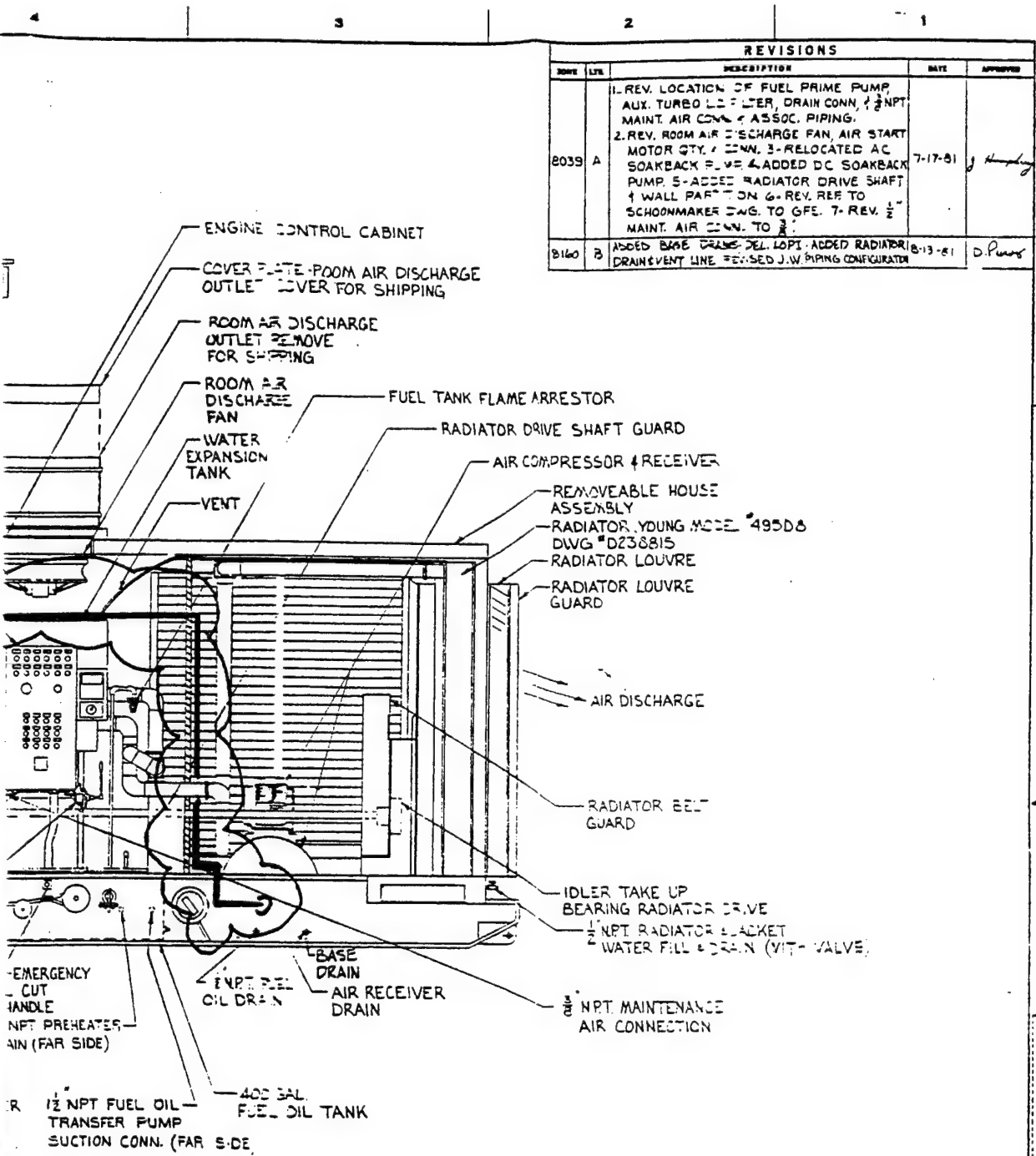
SECTION THRU LIFTING LUGS

TLET

(HAUST SILENCER ASSEMBLY  
REMOVE FOR SHIPPING

ATTACHMENT 1

TYPE		QTY		DESCRIPTION		DATE	
NO.		NO.		DESCRIPTION		DATE	
LIST OF MATERIAL OR PARTS LIST							
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES				CONTRACT NO. <b>N62472-80-C-1648</b> I.W.O. 6039 DAVISVILLE			
MATERIAL QUANTITY UNIT DESCRIPTION				APPROVED DATE CHECKED DATE DRAFTSMAN DATE			
NEXT ASBY USED ON NEXT ASBY FINAL ASBY				ORDER ACTIVITY APPROVAL DATE			
APPLICATION				QTY. REQD.			
				POWER SYS. MORRISON-KNI ROCKY MOUNT, NC TITLE <b>GENERAL ARRA</b> 1500 KW, 4160/240 1200 KW, 3600/210 3F-4W 0.8 PF.			
				D 6E148 6039			
				SCALE 1" = 1'-0" WT.			



REVISIONS				
DATE	BY	DESCRIPTION	DATE	APPROVED
8039	A	1. REV. LOCATION OF FUEL PRIME PUMP, AUX. TURBO L.O. FILTER, DRAIN CONN. 1/2" NPT MAINT. AIR CONN. & ASSOC. PIPING. 2. REV. ROOM AIR DISCHARGE FAN, AIR START MOTOR QTY. & CONN. 3. RELOCATED AC SOAKBACK PUMP & ADDED DC SOAKBACK PUMP. 5-ADDED RADIATOR DRIVE SHAFT 1/2" WALL PARTITION 6-REV. REF TO SCHOONMAKER DWG. TO GFE. 7-REV. 1/2" MAINT. AIR CONN. TO 3.	7-17-81	<i>[Signature]</i>
8140	B	ADDED BASE DRAIN DEL. LOFT. ADDED RADIATOR DRAIN EVENT LINE. REVISED J.W. PIPING CONFIGURATION	8-13-81	D. Purvis

ATTACHMENT 1

ITEM NO.	QTY	DESCRIPTION	UNIT	DATE	BY	APPROVED
<div style="display: flex; justify-content: space-between;"> <div> <p>UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES</p> <p>TOLERANCES ON FINISHES: .005" .010" .015"</p> <p>DATE: 7/11/81</p> <p>DESIGNED BY: <i>[Signature]</i></p> <p>CHECKED BY: <i>[Signature]</i></p> <p>DRAWN BY: <i>[Signature]</i></p> <p>DATE: 7/11/81</p> </div> <div> <p>CONTRACT NO. N62472-80-C-1648</p> <p>I.W.O. 6039</p> <p>DAVISVILLE</p> </div> <div> <p>POWER SYSTEMS DIVISION</p> <p>MORRISON-KNUDSEN COMPANY, INC.</p> <p>REXBY MOUNT, NORTH CAROLINA 27581</p> </div> </div>						
<p>LIST OF MATERIAL OR PARTS LIST</p> <p>GENERAL ARRANGEMENT</p> <p>1500 KW, 4160/2400V 60Hz</p> <p>1200 KW, 3600/2100V 50Hz</p> <p>3P-4W 0.8 P.F.</p>						
APPLICATION		QTY. REQD.		<p>SCALE: 1" = 1'-0" WT.</p> <p>SHEET 1 OF 2</p>		

3

# Engine Gas Manifold

ATTACHMENT 2, Page 1

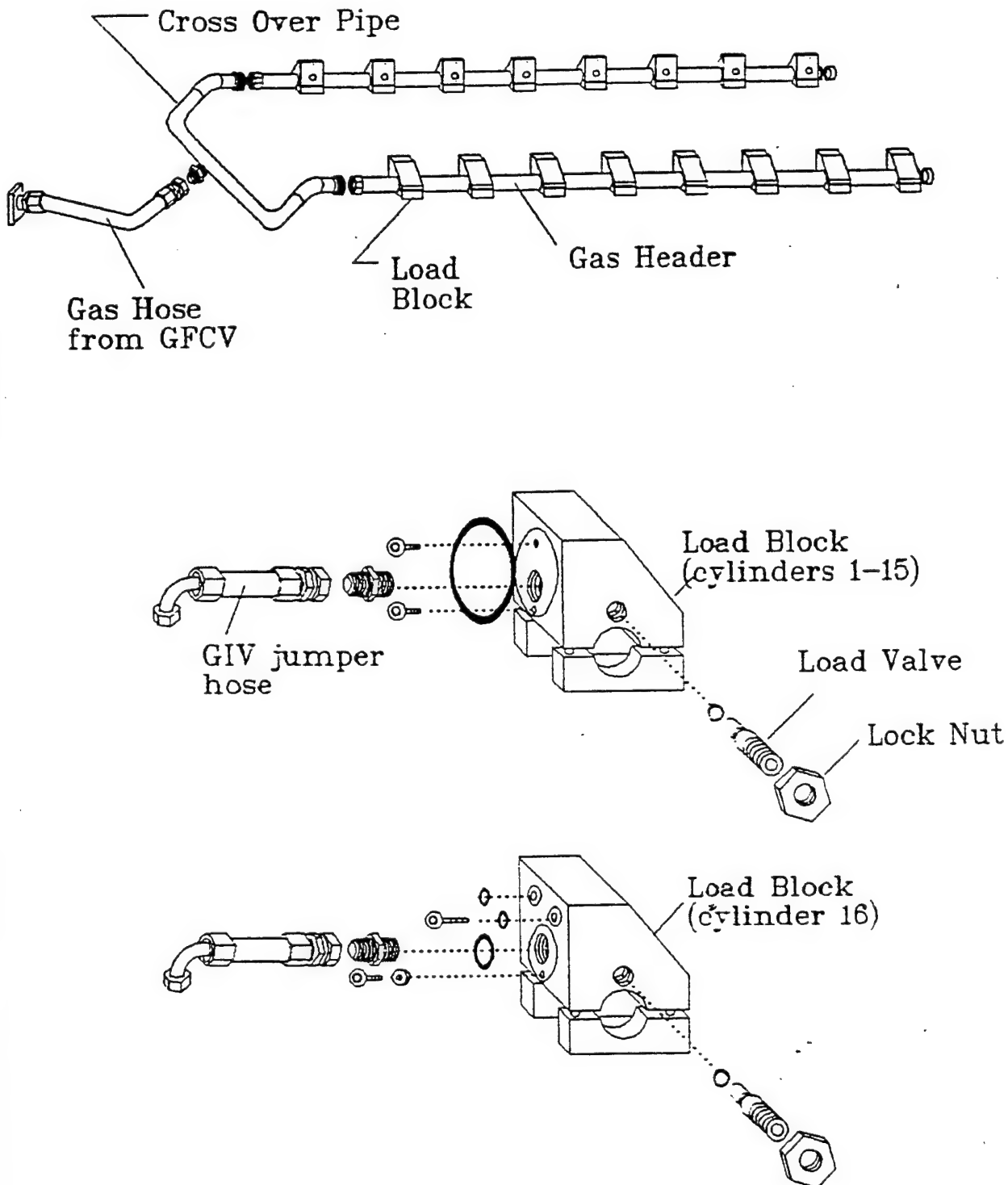
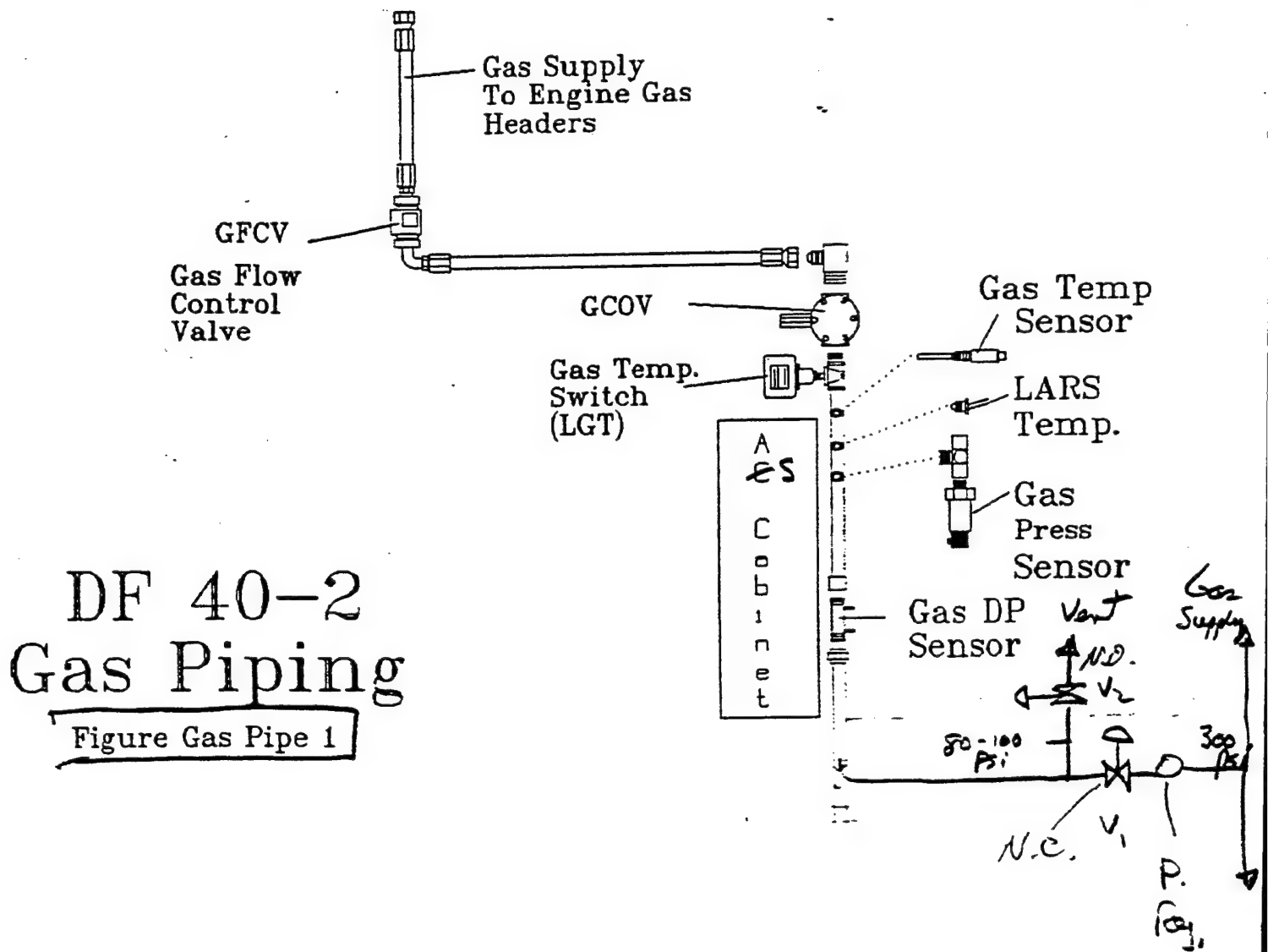


Figure Gas Pipe 2





# DF 40-2 Gas Piping

Figure Gas Pipe 1

## ATTACHMENT 3

### SELF-CHECK SEQUENCE FOR GAS PIPING INTEGRITY

The following sequence of events describes activities which should be directed by the Engine Control Unit (ECU) prior to engine pre-lube and subsequent start up activities:

1. Check gas detector to verify no detection of gas above the 1% by volume threshold (20% LFL).
2. Turn on exhaust fan and verify operation by independent air flow sensor.
3. ECU initiates following activities:
  - a. Close normally open vent valve in gas supply line ( $V_2$  in Attachment 2).
  - b. Freeze all electrical operations requiring the use of spark producing devices (relays, etc.). Turn off any air-heating coils within the engine enclosure.
  - c. Open main gas valve ( $V_1$ ) and gas cutoff valve (GCOV). If relay activation in the ECU is necessary, provide non-sparking relays for these operations.
  - d. After five seconds (maximum), close main gas control valve ( $V_1$ ).
  - e. After a brief time delay (say, 30 seconds), verify that gas pressure sensor indicates a pressure of at least 80 psi (Note: Individual cylinder valves may allow leakage of gas into cylinders for pressures above 85 psig, resulting in a rapid decline in pressure from line pressure to 85 psig.)
  - f. If pressure declines below 80 psi or if gas detector indicates presence of gas over 1% by volume, abort startup sequence and give trouble signal to remote location. Close main gas cutoff valve ( $V_1$ ) and open gas vent valve ( $V_2$ ).
  - g. Otherwise, unfreeze electrical operations in engine enclosure, close cutoff valve (GCOV) and proceed with pre-lube operation.

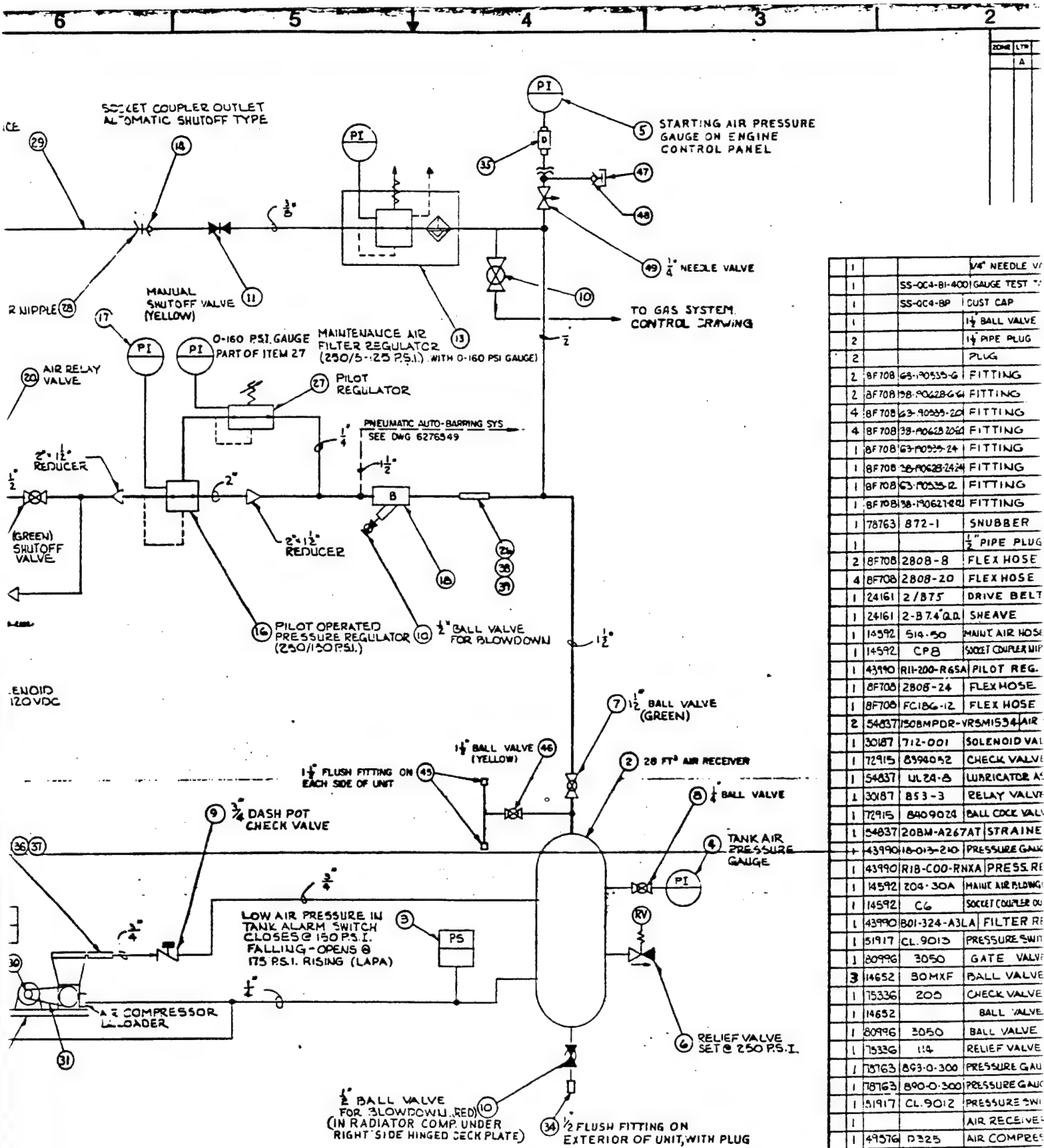
**Appendix B**

**SCHEMATIC DRAWINGS OF DUAL FUEL 1,500 kW CONVERSION OF DIESEL  
POWER PLANTS**

### Included Drawings

<u>Drawing No.</u>	<u>Title</u>
761-DF	Air Start System
766-DF	Jacket Water System
768-DF	Interconnecting Cables
769-DF	Interconnecting Cables Mating Receptacles
772-DF	Switchgear Lineup Plan and Elevation
780-DF	AC Generator
781-DF	Circuit Breaker Control
784-DF	Motor Control Circuits
788-DF	Engine Control Circuits
788A-DF	Engine Control Circuits
788B-DF	Engine Control Circuits
789-DF	Annunciator
790-DF	Engine Control and Subpanel Assembly
791-DF	Engine Control and Subpanel Assembly
965-DF	Metering Cubicle, Door Wiring Diagram
966-DF	Metering Cubicle, Door Wiring Diagram
966A-DF	Metering Cubicle, Right Wall
967-DF	Metering Cubicle, Subpan Wiring Diagram
969-DF	Metering Cubicle, Cable Receptacles Wiring Diagram
970-DF	Circuit Breaker Cubicle, Door Wiring Diagram
971-DF	Circuit Breaker Cubicle, Subpan Wiring Diagram
988-DF	Connection Diagram, Motor Control Center
989-DF	Connection Diagram, MCC Distribution Panel
990-DF	Connection Diagram, Engine Control Panel
990A-DF	Connection Diagram, Engine Control Panel
991-DF	Connection Diagram, Engine Control Panel
993-DF	Connection Diagram, Engine House Equipment
994DF	Connection Diagram, Engine House Equipment





- AIR OPERATED VALVE, SPRING CLOSED
- CHECK VALVE
- SOLENOID VALVE, SPRING CLOSED
- FLEX HOSE
- PIPE PLUG
- SNUBBER
- GATE VALVE, NORMALLY CLOSED

NOTE:  
1. PAINT OPERATING HANDLES OF VALVES THE COLOR INDICATED.

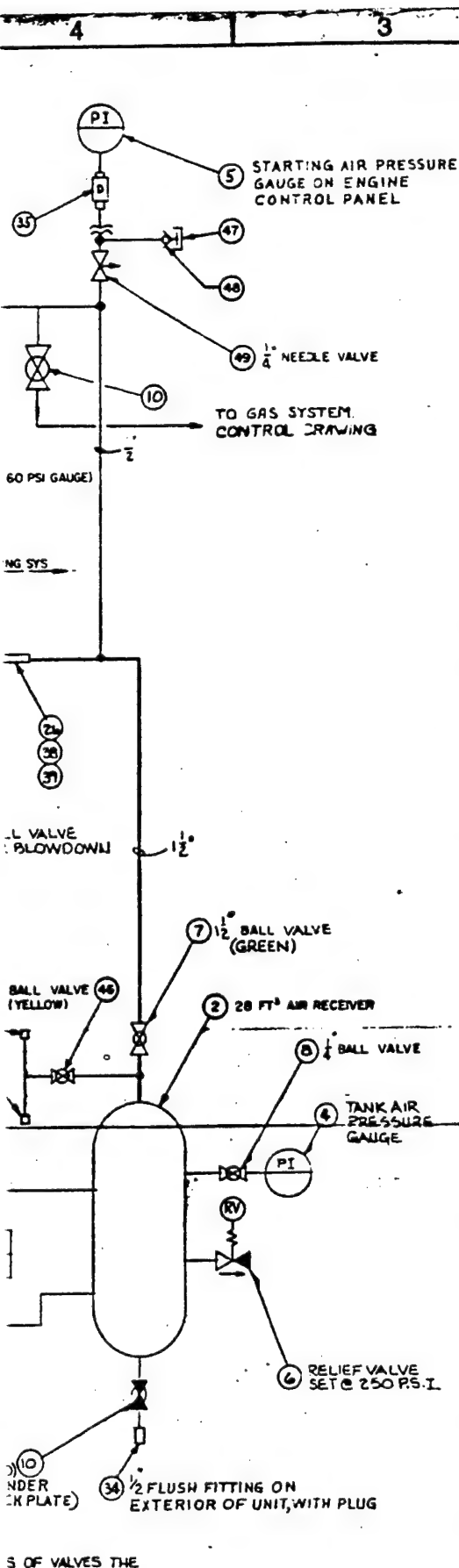
QTY	ITEM NO.	IDENTIFYING NO.	NOMENCLATURE OR DESCRIPTION
1			1/4" NEEDLE VALVE
1		SS-QC4-BI-4001	GAUGE TEST
1		SS-QC4-BP	DUST CAP
1			1 1/2" BALL VALVE
1			1 1/2" PIPE PLUG
2			PLUG
2	8F708	63-10535-G	FITTING
2	8F708	158-90628-G-6	FITTING
4	8F708	63-90628-20	FITTING
4	8F708	38-90628-20	FITTING
1	8F708	63-90535-24	FITTING
1	8F708	38-90628-24	FITTING
1	8F708	63-90535-2	FITTING
1	8F708	38-90628-2	FITTING
1	78763	872-1	SNUBBER
1			1/2" PIPE PLUG
2	8F708	2808-8	FLEX HOSE
4	8F708	2808-20	FLEX HOSE
1	24161	2/B75	DRIVE BELT
1	24161	2-B7.4 Q.D.	SHEAVE
1	14592	514-50	MAINT AIR HOSE
1	14592	CPB	SOCKET COUPLER
1	43990	R11-200-R65A	PILOT REG.
1	8F708	2808-24	FLEX HOSE
1	8F708	FC186-12	FLEX HOSE
2	54037	1508MPDR-VRSM1534	AIR
1	30187	712-001	SOLENOID VAL
1	72915	8394052	CHECK VALVE
1	54037	UL24-B	INDICATOR A
1	30187	853-3	RELAY VALVE
1	72915	8409024	BALL COCK VAL
1	54037	208M-A267AT	STRAINE
1	43990	118-013-210	PRESSURE GAU
1	43990	R18-C00-RNXA	PRESSURE
1	14592	204-30A	MAINT AIR BLDG
1	14592	C6	SOCKET COUPLER
1	43990	B01-324-A31A	FILTER RE
1	51917	CL 9013	PRESSURE SWI
1	80996	3050	GATE VALVE
3	14652	30MXF	PALL VALVE
1	75336	205	CHECK VALVE
1	14652		BALL VALVE
1	80996	3050	BALL VALVE
1	75336	114	RELIEF VALVE
1	75763	893-0-300	PRESSURE GAU
1	78763	890-0-300	PRESSURE GAU
1	51917	CL 9012	PRESSURE SWI
1			AIR RECEIVER
1	49576	D325	AIR COMPRES
1	05472	M361ST	MOTOR

761-

DUEL FUEL 1500 KW  
COMBOSION OF DIESEL POWER PLANTS

SATISFACTORY TO:  
MADE CHIEFS  
NORMAN HUGESON DEC 1994

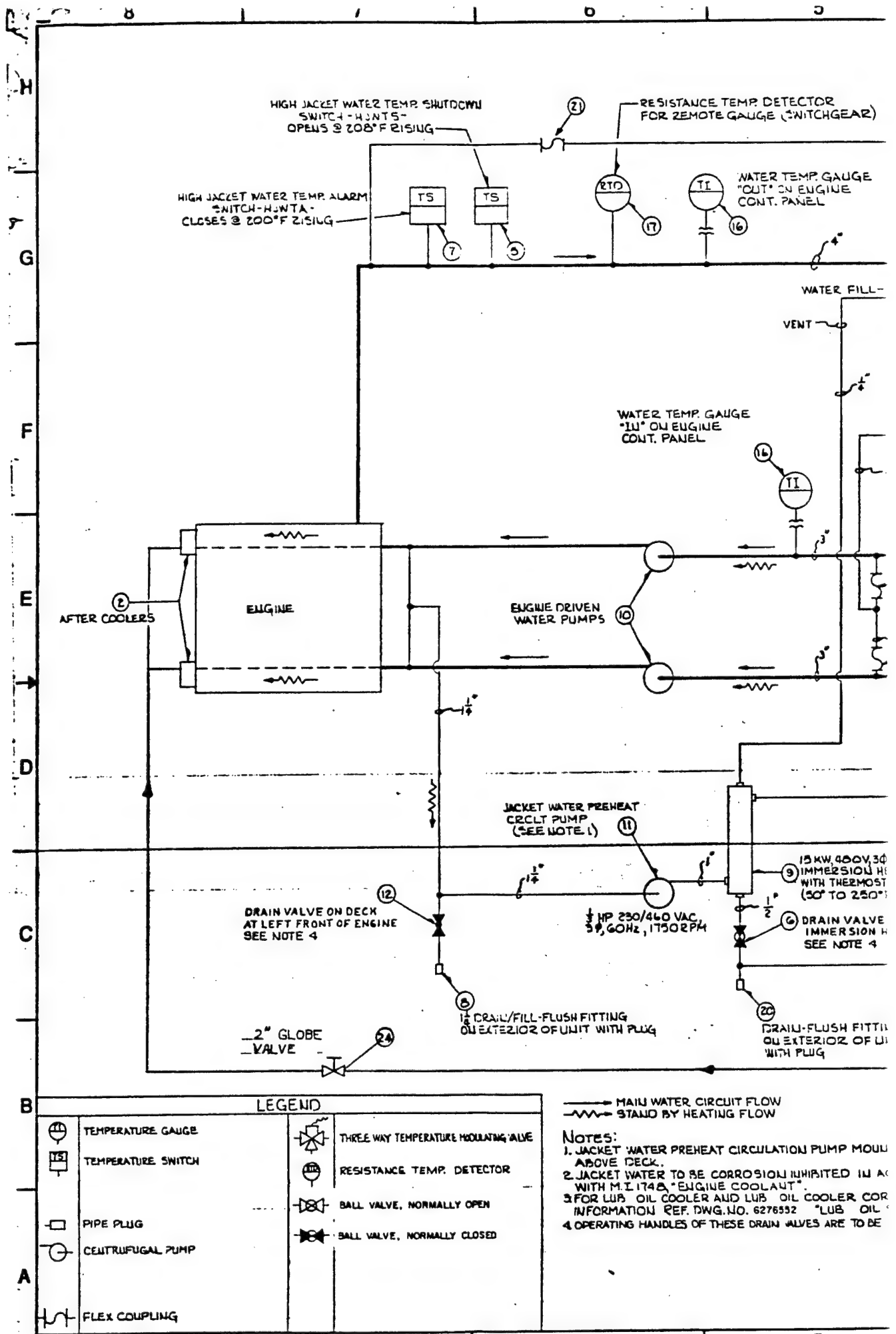
DATE: DEC 1994  
BY: OFFICER



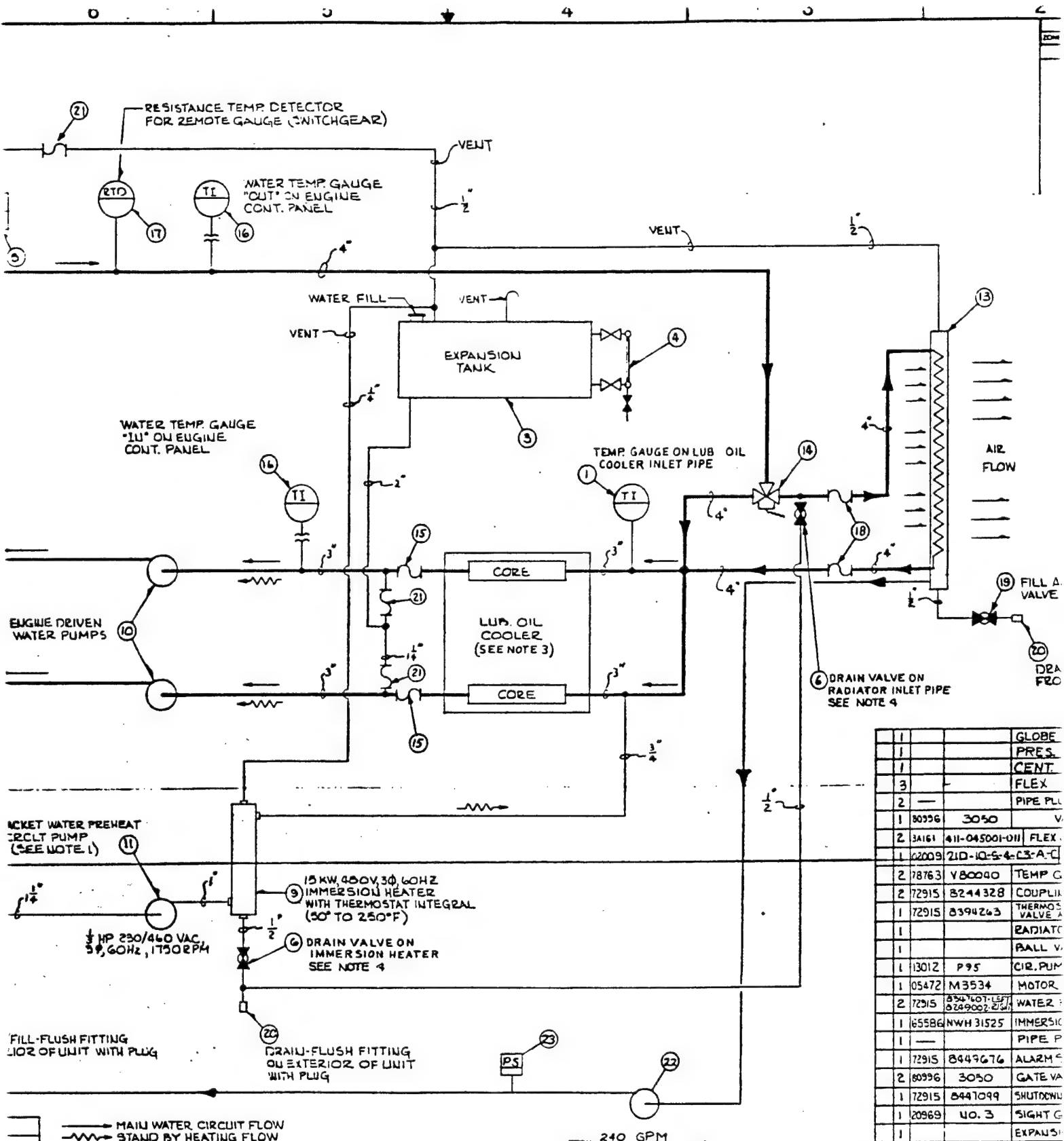
ZONE		DESCRIPTION		DATE	APPROVED
A	SEE	NEESA DCN 92-14		1992-2-14	
1		1/4" NEEDLE VALVE			49
1		SS-0C4-BI-4001 GAUGE TEST "AP"	SWAGELOK - BULKHEAD QUICK-CONNECT		48
1		SS-0C4-BP	DUST CAP		47
1		1 1/2" BALL VALVE			46
2		1 1/2" PIPE PLUG			45
2		1 1/2" PLUG - T-HANDLE CAPTIVE			44
2	8F708	63-10535-G	FITTING	AEROQUIP 3/4" SAE 37° SWIVEL	43
2	8F708	198-10628-G	FITTING	AEROQUIP 3/8" MALE PIPE	42
4	8F708	63-10535-20	FITTING	AEROQUIP 1/2" SAE 37° SWIVEL	41
4	8F708	38-10628-20	FITTING	AEROQUIP 1/2" MALE PIPE	40
1	8F708	63-10535-24	FITTING	AEROQUIP 1 1/2" SAE 37° SWIVEL	39
1	8F708	38-10628-24	FITTING	AEROQUIP 1 1/2" MALE PIPE	38
1	8F708	63-10535-2	FITTING	AEROQUIP 1 1/2" SAE 37° SWIVEL	37
1	8F708	38-10628-2	FITTING	AEROQUIP 1 1/2" MALE PIPE	36
1	78763	872-1	SNUBBER	TRERICE (1/4" NPT)	35
1		1/2" PIPE PLUG			34
2	8F708	2808-8	FLEX HOSE	AEROQUIP	33
4	8F708	2808-20	FLEX HOSE	AEROQUIP	32
1	24161	2-B75	DRIVE BELT	GATES (POWERBAND)	31
1	24161	2-B74 Q.D.	SHEAVE	GATES (W/SK-1 1/2" G.D. BUSHING)	30
1	14592	514-50	MAINT AIR HOSE	AMFLO (50FT)	29
1	14592	CP8	SOCKET COUPLER WIPPLE	AMFLO (3/8" x 1/2" NPT)	28
1	43990	R11-200-R65A	PILOT REG.	NORGREN (15-250 P.S.I. ADJ RANGE, SET @ 150 P.S.I.)	27
1	8F708	2808-24	FLEX HOSE	AEROQUIP	26
1	8F708	FC186-12	FLEX HOSE	AEROQUIP	25
2	54837	150BMPDR-VRSM1534	AIR START MOTOR ASSY	INGERSOLL-RAND	24
1	30187	712-001	SOLENOID VALVE ASSY	SALEM	23
1	72915	8394052	CHECK VALVE	EMD (1/2" FPT)	22
1	54837	UL24-8	LUBRICATOR ASSY	INGERSOLL-RAND (AUTO AIR LINE)	21
1	30187	853-3	RELAY VALVE	SALEM (AIR START, 1 1/2" FPT)	20
1	72915	8409024	BALL COCK VALVE	EMD (1 1/2" FPT)	19
1	54837	208M-A267AT	STRAINER	INGERSOLL-RAND (1 1/2" LINE, Y-TYPE, 1 1/2" FPT)	18
1	43990	R10-013-210	PRESSURE GAUGE	NORGREN - (0-300 P.S.I.)	17
1	43990	R11-000-RNXX	PRESS REG.	NORGREN (250/150 P.S.I., 1/2" NPT)	16
1	14592	204-30A	MAINT AIR BLOWDOWN	AMFLO	15
1	14592	C6	SOCKET COUPLER OUTLET	AMFLO (3/8" x 1/2" NPT)	14
1	43990	B01-324-A3LA	FILTER REG.	NORGREN (250/5-125 P.S.I., 3/8" UPT)	13
1	51917	CL 9013	PRESSURE SWITCH	SQUARE D (TYPE GHW-5)	12
1	80996	3050	GATE VALVE	GRINNELL (1/2" UPT)	11
3	14652	30MXF	FALL VALVE	UNITED BRASS (1/2" UPT)	10
1	75336	205	CHECK VALVE	KINGSTON (DASH POT, 3/4" UPT)	9
1	14652		BALL VALVE	WHITEY (1/4", SWAGELOK)	8
1	80996	3050	BALL VALVE	GRINNELL (1 1/2" UPT)	7
1	75336	114	RELIEF VALVE	KINGSTON (1/2" NPT, SET @ 250 P.S.I.)	6
1	78763	893-0-300	PRESSURE GAUGE	TRERICE (0-300 P.S.I.)	5
1	78763	890-0-300	PRESSURE GAUGE	TRERICE (0-300 P.S.I.)	4
1	51917	CL 9012	PRESSURE SWITCH	SQUARE D (TYPE GAW-4)	3
1			AIR RECEIVER	(28 FT³ HORIZ)	2
1	49576	D325	AIR COMPRES.	QUINCY (W/7970X1 UNLOADER)	1
1	05472	M3615T	MOTOR	BALDOR (5HP, 240 VAC, 3Φ)	A

3 OF VALVES THE

761-DF DEPARTMENT OF THE NAVY NAVAL ENERGY AND ENVIRONMENTAL SUPPORT ACTIVITY NEW HARBOR, CALIFORNIA 92343-5004		OVERHAUL 1500 KW DIESEL POWER PLANTS AIR START SYSTEM SCHEMATIC	
DUEL FUEL 1500 KW COMPOSITION OF DIESEL POWER PLANTS		6276548 F 80091 CASE NO. 6276548 DATE 11/1/92 SCALE NONE	
SATISFACTORY TO NAME: NORMAN HIGGSON DATE: DEC 1992		SHEET 2 OF 2	







- MAIN WATER CIRCUIT FLOW  
 ~~~~~ STAND BY HEATING FLOW
- NOTES:**  
 1. JACKET WATER PREHEAT CIRCULATION PUMP MOUNTED ABOVE DECK.  
 2. JACKET WATER TO BE CORROSION INHIBITED IN ACCORDANCE WITH M.I. 1748 "ENGINE COOLANT".  
 3. FOR LUB. OIL COOLER AND LUB. OIL COOLER CORE. INFORMATION REF. DWG. NO. 6276352 "LUB. OIL SCHEMATIC".  
 4. OPERATING HANDLES OF THESE DRAIN VALVES ARE TO BE PAINTED RED.

|   |       |                   |               |
|---|-------|-------------------|---------------|
| 1 |       |                   | GLOBE         |
| 1 |       |                   | PRES.         |
| 1 |       |                   | CENT.         |
| 3 |       |                   | FLEX.         |
| 2 |       |                   | PIPE PL.      |
| 1 | 80996 | 3050              | V.            |
| 2 | 3A161 | 411-045001-011    | FLEX.         |
| 1 | 02009 | 21D-10-5-4-C3-A-C |               |
| 2 | 78763 | V800040           | TEMP. G.      |
| 2 | 72915 | 8244328           | COUPLIN.      |
| 1 | 72915 | 8394263           | THERMO. VALVE |
| 1 |       |                   | RADIATOR      |
| 1 |       |                   | BALL V.       |
| 1 | 13012 | P95               | CIR. PUM.     |
| 1 | 05472 | M3534             | MOTOR         |
| 2 | 72915 | 854101-151        | WATER         |
| 1 | 65586 | NWH 31525         | IMMERSIC.     |
| 1 |       |                   | PIPE P.       |
| 1 | 72915 | 8449676           | ALARM S.      |
| 2 | 80996 | 3050              | GATE VA.      |
| 1 | 72915 | 8447099           | SHUTDOWN      |
| 1 | 20969 | NO. 3             | SIGHT G.      |
| 1 |       |                   | EXPANS.       |
| 2 | 72915 | 8409891           | AFTER C.      |
| 1 | 72915 | 8031666           | TEMP. G.      |

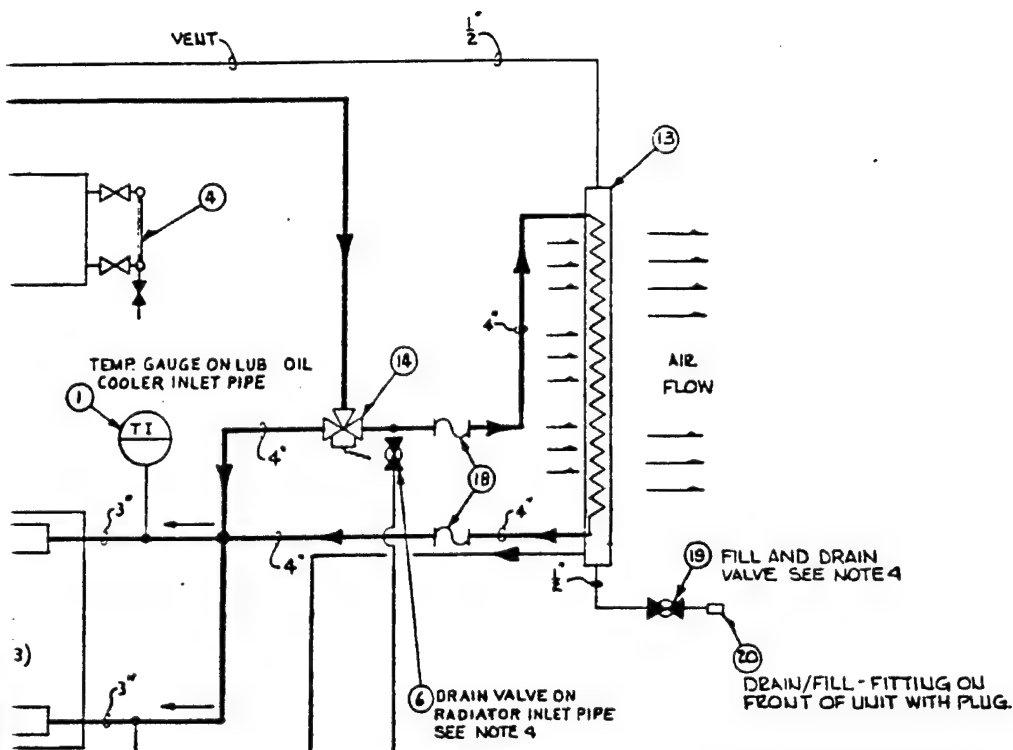
1500 kW  
 IDENTIFYING NO.  
 NOMENCLATURE

DUEL FUEL 1500 KW  
 CONVERSION OF DIESEL POWER PLANTS

SATISFACTORY TO:  
 NAME: CHILDS  
 POSITION: JR. DESIGNER  
 DATE: DEC. 1958

76

| REVISIONS |     | DATE                | APPROVED  |
|-----------|-----|---------------------|-----------|
| ZONE      | LTR | DESCRIPTION         |           |
| A         |     | SEE NEESA DCN 92-16 | 1992-2-18 |



|                                                                                                       |       |                               |                           |                                                                         |    |
|-------------------------------------------------------------------------------------------------------|-------|-------------------------------|---------------------------|-------------------------------------------------------------------------|----|
|                                                                                                       |       |                               | GLOBE VALVE               | 2" NPT                                                                  | 24 |
| 1                                                                                                     |       |                               | PRES. SWCH                | SQUARE "D"/GAW-4 SER.B (1.5-75PSI)                                      | 23 |
| 1                                                                                                     |       |                               | CENT. PUMP                | 240 GPM                                                                 | 22 |
| 3                                                                                                     |       |                               | FLEX                      | AEROQUIP (FLEX)                                                         | 21 |
| 2                                                                                                     |       |                               | PIPE PLUG                 | (1/2")                                                                  | 20 |
| 1                                                                                                     | 80996 | 3050                          | VALVE                     | GRINNELL (1/2")                                                         | 19 |
| 2                                                                                                     | 3A161 | 411-045001-011                | FLEX JOINT                | ROCKWELL (4")                                                           | 18 |
| 1                                                                                                     | 62009 | 21D-10-S-4-C3-A-C             | DETECTOR R&F              | (JACKET WATER TEMP. RTD)                                                | 17 |
| 2                                                                                                     | 78763 | Y80040                        | TEMP. GAUGE               | TRERICE (JACKET WATER - 30-240°F)                                       | 16 |
| 2                                                                                                     | 72915 | 8244328                       | COUPLING ASSY.            | EMD (FLEX)                                                              | 15 |
| 1                                                                                                     | 72915 | 8394243                       | THERMOSTAT VALVE ASSEMBLY | EMD (W/8332066 180°F ELEMENTS)                                          | 14 |
| 1                                                                                                     |       |                               | RADIATOR ASSY.            | MESABI                                                                  | 13 |
| 1                                                                                                     |       |                               | BALL VALVE                | (1 1/2", FPT)                                                           | 12 |
| 1                                                                                                     | 13012 | P95                           | CIR. PUMP                 | PRICE (1 1/2" x 1" USE MECHANICAL SEAL PART 180538 FOR ETHYLENE-GLYCOL) | 11 |
| 1                                                                                                     | 05472 | M3534                         | MOTOR                     | BALDOR (1/2 HP, 460 VAC, 3Ø, 1725 RPM)                                  | 10 |
| 2                                                                                                     | 72915 | 8541601-LEFT<br>8249002-RIGHT | WATER PUMP                | EMD (ENG. DRIVEN - 1EA-LEFT & RIGHT)                                    | 9  |
| 1                                                                                                     | 65586 | NWH 31525                     | IMMERSION HTZ.            | CHROMALOX (15KV, 480VAC, 3Ø, W/AR2525 THERMO)                           | 8  |
| 1                                                                                                     |       |                               | PIPE PLUG                 | (1 1/2")                                                                | 7  |
| 1                                                                                                     | 72915 | 8449676                       | ALARM SWITCH              | EMD (HIGH WATER TEMP. - 200°F)                                          | 6  |
| 2                                                                                                     | 80996 | 3050                          | GATE VALVE                | GRINNELL (1/2" NPT)                                                     | 5  |
| 1                                                                                                     | 72915 | 8447099                       | SHUTDOWN SWITCH           | EMD (HIGH WATER TEMP. - 208°F)                                          | 4  |
| 1                                                                                                     | 20969 | 40.3                          | SIGHT GLASS               | ESSEX BRASS (INCL. 2 GAUGE COCKS & DRAIN COCK)                          | 3  |
| 1                                                                                                     |       |                               | EXPANSION TANK            |                                                                         | 2  |
| 2                                                                                                     | 72915 | 8409891                       | AFTER COOLER              | EMD (CORE P/N 8352305)                                                  | 1  |
| 1                                                                                                     | 72915 | 8031666                       | TEMP. GAUGE               | EMD (JACKET WATER - 30°-300°F)                                          | 1  |
| ITEM NO. FROM NO. PART OR IDENTIFYING NO. NOMENCLATURE OR DESCRIPTION MATERIAL SPECIFICATION ITEM NO. |       |                               |                           |                                                                         |    |

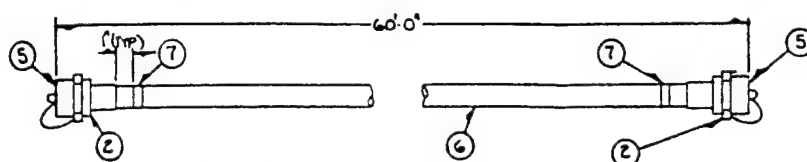
|                                                        |  |                                                                                                                                               |  |
|--------------------------------------------------------|--|-----------------------------------------------------------------------------------------------------------------------------------------------|--|
| DUEL FUEL 1500 KW<br>CONVERSION OF DIESEL POWER PLANTS |  | 766-DF<br>REPAIR OF THE 1500 KW DIESEL POWER PLANTS<br>NAVAL ENERGY AND ENVIRONMENTAL SUPPORT ACTIVITY<br>PERRY HARBOR, CALIFORNIA 92040-2004 |  |
| SATISFACTION TO:<br>LIEUT. COL. J. P. JENSEN, DEC 1994 |  | OVERHAUL 1500 KW<br>DIESEL POWER PLANTS<br>JACKET WATER SYSTEM SCHEMATIC                                                                      |  |
| DATE: 10/10/94<br>BY: J. P. JENSEN                     |  | CASE NO: 6276553<br>DRAWING NO: N47408-89-C-2011                                                                                              |  |
| SCALE: NONE                                            |  | SHEET: 7 OF 7                                                                                                                                 |  |

240 GPM  
CENTRIFUGAL PUMP

SWITCHGEAR CONTROL UNIT END

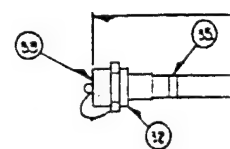
ENGINE GENERATOR UNIT END

SWITCHGEAR CONTROL UNIT

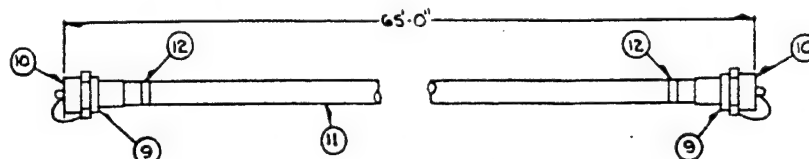


CABLE - 8 GROUPS TWISTED SHIELDED  
PAIRS #20 AWG  
PAIRS INDIVIDUALLY SHIELDED WITH DRAIN WIRE,  
OVERALL SHIELD WITH DRAIN WIRE  
600 VOLT INSULATION CLASS  
RATED FOR 105°C

① CABLE "A" - INSTRUMENTATION CABLE

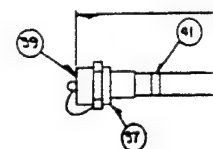


③1 CABLE

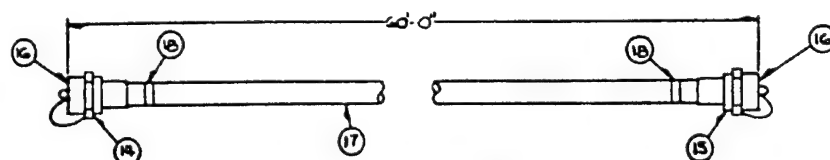


CABLE - 40 CONDUCTOR #14 AWG  
600 VOLT INSULATION TYPE 50W-A  
RATED FOR 90°C

⑧ CABLE "B" - CONTROL CABLE

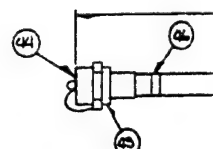


③6 CABLE "

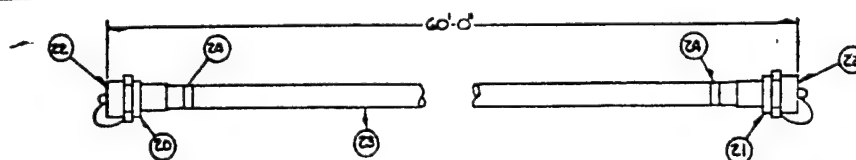


CABLE - 3 CONDUCTOR #4 AWG  
WITH 1-#12 GROUND WIRE  
600 VOLT INSULATION  
RATED FOR 90°C

⑬ CABLE "C" - 480 VAC STATION POWER CABLE

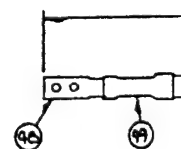


④2 CABLE "



CABLE - 3 CONDUCTOR #6 AWG  
600 VOLT INSULATION TYPE 50  
RATED FOR 90°C

⑬ CABLE "D" - 120/240 STATION POWER CABLE



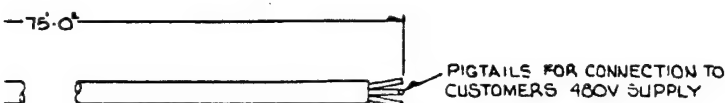
④7 C  
GENERATOR

⑤⑤ CABLE "J" - CONTROL CABLE (ECW)  
SAME AS CABLE "B" ABOVE

⑤⑥ C

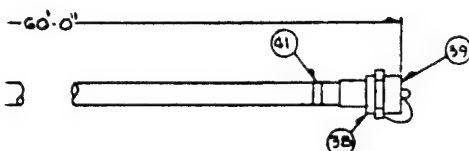


ENGINE GENERATOR UNIT END  
(EXCEPT CABLE 'F')



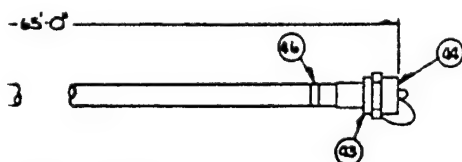
FOR \*2AWG WITH #10 GROUND  
SECTION

Power Cable



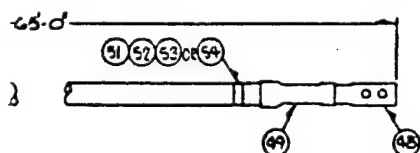
FOR \*10 AWG  
SECTION

Power & Emer. Lighting Cable



FOR \*14 AWG  
NON TYPE 50W-A

FOR CABLE



10 AWG  
N

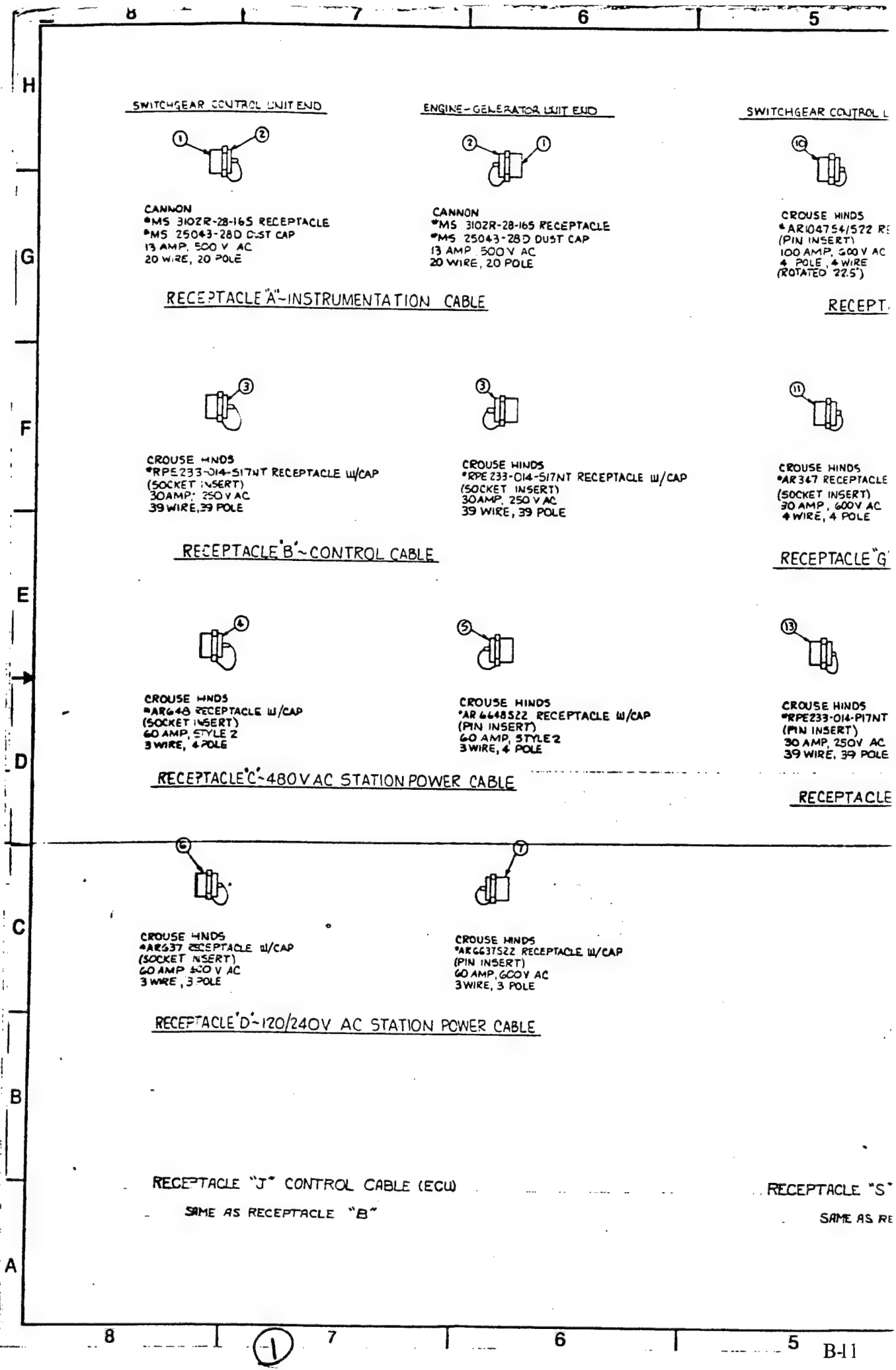
FOR CABLE BETWEEN  
SECTION BOX & SWITCHGEAR CONTROL UNIT

COMMUNICATIONS CABLE

| REVISIONS |     |                    |           |
|-----------|-----|--------------------|-----------|
| ZONE      | LTN | DESCRIPTION        | DATE      |
| A         |     | SEE NEESA DCN 92-1 | 1992-11-6 |

|         |         |         |                |                                                         |                                                  |    |
|---------|---------|---------|----------------|---------------------------------------------------------|--------------------------------------------------|----|
|         |         |         | CABLE ASS'Y.   | CABLE "S" COMM. CABLE                                   | 56                                               |    |
|         |         |         | CABLE ASS'Y.   | CABLE "J" (ITEMS 9-12)                                  | 55                                               |    |
|         | 2       | 80607   | METAL TAG      | "U"                                                     | 54                                               |    |
|         | 2       | 80607   | METAL TAG      | "T-3"                                                   | 53                                               |    |
|         | 2       | 80607   | METAL TAG      | "T-2"                                                   | 52                                               |    |
|         | 2       | 80607   | METAL TAG      | "T-1"                                                   | 51                                               |    |
|         | 2       | 57672   | 3R-2021        | CABLE                                                   | ANNUNCIATOR (1 COND. 2/0 AWG, 5/15 KV)           | 50 |
|         | 2       | 41056   | 54031-2        | HEAT SHRIEK                                             | AMP                                              | 49 |
|         | 2       | 41056   | 53681-2        | LUG                                                     | AMP (2/0 NEMA 2 HOLE, COMPRESSOR)                | 48 |
|         | 4       |         | CABLE ASSY.    | GENERATOR POWER (ITEMS 48-50 & 51-54)                   | 47                                               |    |
|         | 2       | 80607   | METAL TAG      | "ANNUNCIATOR"                                           | 46                                               |    |
|         | 2       | 57672   | 4A-1440        | CABLE                                                   | ANNUNCIATOR (40 COND. #14 AWG, 600 VOLT)         | 45 |
|         | 2       | 50539   | RPE033-008     | DUST CAP                                                | CROUSE HINDS                                     | 44 |
|         | 2       | 50539   | RPEM133-338    | -SITNT PLUG                                             | CROUSE HINDS (39 WIRE, 39 POLE, FEMALE)          | 43 |
|         | 1       |         | CABLE ASSY.    | CABLE "H" ~ ANNUNCIATOR (ITEMS 43-46)                   | 42                                               |    |
|         | 2       | 80607   | METAL TAG      | "125 VDC POWER & EMERG. LTS."                           | 41                                               |    |
|         | 2       | 57672   | 4A-1004        | CABLE                                                   | ANNUNCIATOR (4 COND. #10 AWG, 600 VOLT)          | 40 |
|         | 2       | 50539   | CPK13          | DUST CAP                                                | CROUSE HINDS                                     | 39 |
|         | 1       | 50539   | APJ3475522     | PLUG                                                    | CROUSE HINDS (4 WIRE, 4 POLE, FEMALE)            | 38 |
|         | 1       | 50539   | APJ3475        | PLUG                                                    | CROUSE HINDS (4 WIRE, 4 POLE, MALE)              | 37 |
|         | 1       |         | CABLE ASSY.    | CABLE "G" ~ 125 VDC POWER & EMERG. LIGHTS (ITEMS 37-41) | 36                                               |    |
|         | 1       | 80607   | METAL TAG      | "SHORE POWER"                                           | 35                                               |    |
|         | 2       | 57672   | HO2216         | CABLE                                                   | HOUSTON (3 COND. #2 AWG, #11 #10 GND)            | 34 |
|         | 1       | 50539   | CPK64          | DUST CAP                                                | CROUSE HINDS                                     | 33 |
|         | 1       | 50539   | APJ1047754/522 | PLUG                                                    | CROUSE HINDS (4 WIRE, 4 POLE, FEMALE OFFSET 70°) | 32 |
|         | 1       |         | CABLE ASSY.    | CABLE "F" ~ SHORE POWER (ITEMS 32-35)                   | 31                                               |    |
|         |         |         | (REMOVED)      |                                                         | 30                                               |    |
|         |         |         | (REMOVED)      |                                                         | 29                                               |    |
|         |         |         | (REMOVED)      |                                                         | 28                                               |    |
|         |         |         | (REMOVED)      |                                                         | 27                                               |    |
|         |         |         | (REMOVED)      |                                                         | 26                                               |    |
|         |         |         | (REMOVED)      |                                                         | 25                                               |    |
|         | 2       | 80607   | METAL TAG      | "120/240 VAC STATION POWER"                             | 24                                               |    |
|         | 2       | 57672   | 4A-0603        | CABLE                                                   | ANNUNCIATOR (3 COND. #6 AWG, 600 VOLT)           | 23 |
|         | 2       | 50539   | CPK32          | DUST CAP                                                | CROUSE HINDS                                     | 22 |
|         | 1       | 50539   | APJ6375522     | PLUG                                                    | CROUSE HINDS (3 WIRE, 3 POLE, FEMALE)            | 21 |
|         | 1       | 50539   | APJ6375        | PLUG                                                    | CROUSE HINDS (3 WIRE, 3 POLE, MALE)              | 20 |
|         | 1       |         | CABLE ASSY.    | CABLE "D" ~ 120/240 VAC STATION POWER (ITEMS 20-24)     | 19                                               |    |
|         | 2       | 80607   | METAL TAG      | "480 VAC STATION POWER"                                 | 18                                               |    |
|         | 2       | 57672   | HO2214         | CABLE                                                   | HOUSTON (3 COND. #4 AWG, #12 GND)                | 17 |
|         | 2       | 50539   | CPK34          | DUST CAP                                                | CROUSE HINDS                                     | 16 |
|         | 1       | 50539   | APJ6485522     | PLUG                                                    | CROUSE HINDS (3 WIRE, 4 POLE, FEMALE)            | 15 |
|         | 1       | 50539   | APJ6485        | PLUG                                                    | CROUSE HINDS (3 WIRE, 4 POLE, MALE)              | 14 |
|         | 1       |         | CABLE ASSY.    | CABLE "C" ~ 480 VAC STATION POWER (ITEMS 14-18)         | 13                                               |    |
|         | 2       | 80607   | METAL TAG      | "CONTROL"                                               | 12                                               |    |
|         | 2       | 57672   | 4A-1440        | CABLE                                                   | ANNUNCIATOR (40 COND. #14 AWG, 600 VOLT)         | 11 |
|         | 2       | 50539   | RPE033-008     | DUST CAP                                                | CROUSE HINDS                                     | 10 |
|         | 2       | 50539   | RPEM133-388    | -SITNT PLUG                                             | CROUSE HINDS (39 WIRE, 39 POLE, MALE)            | 9  |
|         | 1       |         | CABLE ASSY.    | CABLE "B" ~ CONTROL (ITEMS 9-12)                        | 8                                                |    |
|         | 2       | 80607   | METAL TAG      | "INSTRUMENTATION"                                       | 7                                                |    |
|         | 2       | 57672   | H10303         | CABLE                                                   | HOUSTON (8 GPS-TWISTED SHIELDED PAIRS #10 AWG)   | 6  |
|         | 2       | 08051   | M525042-28D    | DUST CAP                                                | CANNON                                           | 5  |
|         |         |         |                | N/A                                                     | 4                                                |    |
|         |         |         |                | N/A                                                     | 3                                                |    |
|         | 2       | 08051   | M53106F-28-16P | PLUG                                                    | CANNON (20 WIRE, 20 POLE, MALE)                  | 2  |
|         | 1       |         | CABLE ASSY.    | CABLE "A" ~ INSTRUMENTATION (ITEMS 2-7)                 | 1                                                |    |
| QTY REQ | QTY REQ | QTY REQ | QTY REQ        | QTY REQ                                                 | QTY REQ                                          |    |
|         | QTY REQ | QTY REQ | QTY REQ        | QTY REQ                                                 | QTY REQ                                          |    |
|         | QTY REQ | QTY REQ | QTY REQ        | QTY REQ                                                 | QTY REQ                                          |    |
|         | QTY REQ | QTY REQ | QTY REQ        | QTY REQ                                                 | QTY REQ                                          |    |
|         | QTY REQ | QTY REQ | QTY REQ        | QTY REQ                                                 | QTY REQ                                          |    |
|         | QTY REQ | QTY REQ | QTY REQ        | QTY REQ                                                 | QTY REQ                                          |    |
|         | QTY REQ | QTY REQ | QTY REQ        | QTY REQ                                                 | QTY REQ                                          |    |
|         | QTY REQ | QTY REQ | QTY REQ        | QTY REQ                                                 | QTY REQ                                          |    |
|         | QTY REQ | QTY REQ | QTY REQ        | QTY REQ                                                 | QTY REQ                                          |    |
|         | QTY REQ | QTY REQ | QTY REQ        | QTY REQ                                                 | QTY REQ                                          |    |
|         | QTY REQ | QTY REQ | QTY REQ        | QTY REQ                                                 | QTY REQ                                          |    |
|         | QTY REQ | QTY REQ | QTY REQ        | QTY REQ                                                 | QTY REQ                                          |    |
|         | QTY REQ | QTY REQ | QTY REQ        | QTY REQ                                                 | QTY REQ                                          |    |
|         | QTY REQ | QTY REQ | QTY REQ        | QTY REQ                                                 | QTY REQ                                          |    |
|         | QTY REQ | QTY REQ | QTY REQ        | QTY REQ                                                 | QTY REQ                                          |    |
|         | QTY REQ | QTY REQ | QTY REQ        | QTY REQ                                                 | QTY REQ                                          |    |
|         | QTY REQ | QTY REQ | QTY REQ        | QTY REQ                                                 | QTY REQ                                          |    |
|         | QTY REQ | QTY REQ | QTY REQ        | QTY REQ                                                 | QTY REQ                                          |    |
|         | QTY REQ | QTY REQ | QTY REQ        | QTY REQ                                                 | QTY REQ                                          |    |
|         | QTY REQ | QTY REQ | QTY REQ        | QTY REQ                                                 | QTY REQ                                          |    |
|         | QTY REQ | QTY REQ | QTY REQ        | QTY REQ                                                 | QTY REQ                                          |    |
|         | QTY REQ | QTY REQ | QTY REQ        | QTY REQ                                                 | QTY REQ                                          |    |
|         | QTY REQ | QTY REQ | QTY REQ        | QTY REQ                                                 | QTY REQ                                          |    |
|         | QTY REQ | QTY REQ | QTY REQ        | QTY REQ                                                 | QTY REQ                                          |    |
|         | QTY REQ | QTY REQ | QTY REQ        | QTY REQ                                                 | QTY REQ                                          |    |
|         | QTY REQ | QTY REQ | QTY REQ        | QTY REQ                                                 | QTY REQ                                          |    |
|         | QTY REQ | QTY REQ | QTY REQ        | QTY REQ                                                 | QTY REQ                                          |    |
|         | QTY REQ | QTY REQ | QTY REQ        | QTY REQ                                                 | QTY REQ                                          |    |
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|         | QTY REQ | QTY REQ | QTY REQ        | QTY REQ                                                 | QTY REQ                                          |    |
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|         | QTY REQ | QTY REQ | QTY REQ        | QTY REQ                                                 | QTY REQ                                          |    |
|         | QTY REQ | QTY REQ | QTY REQ        | QTY REQ                                                 | QTY REQ                                          |    |
|         | QTY REQ | QTY REQ | QTY REQ        | QTY REQ                                                 | QTY REQ                                          |    |
|         | QTY REQ | QTY REQ | QTY REQ        | QTY REQ                                                 | QTY REQ                                          |    |
|         | QTY REQ | QTY REQ | QTY REQ        | QTY REQ                                                 | QTY REQ                                          |    |
|         | QTY REQ | QTY REQ | QTY REQ        | QTY REQ                                                 | QTY REQ                                          |    |
|         | QTY REQ | QTY REQ | QTY REQ        | QTY REQ                                                 | QTY REQ                                          |    |
|         | QTY REQ | QTY REQ | QTY REQ        | QTY REQ                                                 | QTY REQ                                          |    |
|         | QTY REQ | QTY REQ | QTY REQ        | QTY REQ                                                 | QTY REQ                                          |    |
|         | QTY REQ | QTY REQ | QTY REQ        | QTY REQ                                                 | QTY REQ                                          |    |
|         | QTY REQ | QTY REQ | QTY REQ        | QTY REQ                                                 | QTY REQ                                          |    |
|         | QTY REQ | QTY REQ | QTY REQ        | QTY REQ                                                 | QTY REQ                                          |    |
|         | QTY REQ | QTY REQ | QTY REQ        | QTY REQ                                                 | QTY REQ                                          |    |
|         | QTY REQ | QTY REQ | QTY REQ        | QTY REQ                                                 | QTY REQ                                          |    |
|         | QTY REQ | QTY REQ | QTY REQ        | QTY REQ                                                 | QTY REQ                                          |    |
|         | QTY REQ | QTY REQ | QTY REQ        | QTY REQ                                                 | QTY REQ                                          |    |
|         | QTY REQ | QTY REQ | QTY REQ        | QTY REQ                                                 | QTY REQ                                          |    |
|         | QTY REQ | QTY REQ | QTY REQ        | QTY REQ                                                 | QTY REQ                                          |    |
|         | QTY REQ | QTY REQ | QTY REQ        | QTY REQ                                                 | QTY REQ                                          |    |
|         | QTY REQ | QTY REQ | QTY REQ        | QTY REQ                                                 | QTY REQ                                          |    |
|         | QTY REQ | QTY REQ | QTY REQ        | QTY REQ                                                 | QTY REQ                                          |    |
|         | QTY REQ | QTY REQ | QTY REQ        | QTY REQ                                                 | QTY REQ                                          |    |
|         | QTY REQ | QTY REQ | QTY REQ        | QTY REQ                                                 | QTY REQ                                          |    |
|         | QTY REQ | QTY REQ | QTY REQ        | QTY REQ                                                 | QTY REQ                                          |    |

|                                                        |  |                                                                   |  |
|--------------------------------------------------------|--|-------------------------------------------------------------------|--|
| DUEL FUEL 1500 KW<br>CONVERSION OF DIESEL POWER PLANTS |  | OVERHAUL 1500 KW<br>DIESEL POWER PLANTS<br>INTERCONNECTING CABLES |  |
| SATISFACTORY TO:<br>NORMAN H. JOHNSON, CHIEF, 1998     |  | DATE: 1/4/98                                                      |  |
| APPROVED: [Signature]                                  |  | DATE: 1/4/98                                                      |  |
| PART NO. IDENTIFYING NO.                               |  | MATERIAL/SPECIFICATION                                            |  |
| 768-DF                                                 |  | 6276555                                                           |  |
| F 80091                                                |  | NONE                                                              |  |



SWITCHGEAR CONTROL UNIT END

ENGINE-GENERATOR UNIT END

SWITCHGEAR CONTROL L



CANNON  
 \*MS 3102R-28-16S RECEPTACLE  
 \*MS 25043-28D DUST CAP  
 13 AMP, 500 V AC  
 20 WIRE, 20 POLE

CANNON  
 \*MS 3102R-28-16S RECEPTACLE  
 \*MS 25043-28D DUST CAP  
 13 AMP, 500 V AC  
 20 WIRE, 20 POLE

CROUSE HINDS  
 \*AR104754/522 R  
 (PIN INSERT)  
 100 AMP, 600 V AC  
 4 POLE, 4 WIRE  
 (ROTATED 22.5°)

RECEPTACLE "A"-INSTRUMENTATION CABLE

RECEPT.



CROUSE HINDS  
 \*RPE233-014-S17NT RECEPTACLE W/CAP  
 (SOCKET INSERT)  
 30 AMP, 250 V AC  
 39 WIRE, 39 POLE

CROUSE HINDS  
 \*RPE233-014-S17NT RECEPTACLE W/CAP  
 (SOCKET INSERT)  
 30 AMP, 250 V AC  
 39 WIRE, 39 POLE

CROUSE HINDS  
 \*AR347 RECEPTACLE  
 (SOCKET INSERT)  
 30 AMP, 600V AC  
 4 WIRE, 4 POLE

RECEPTACLE "B"-CONTROL CABLE

RECEPTACLE "G"



CROUSE HINDS  
 \*AR648 RECEPTACLE W/CAP  
 (SOCKET INSERT)  
 60 AMP, STYLE 2  
 3 WIRE, 4 POLE

CROUSE HINDS  
 \*AR648S22 RECEPTACLE W/CAP  
 (PIN INSERT)  
 60 AMP, STYLE 2  
 3 WIRE, 4 POLE

CROUSE HINDS  
 \*RPE233-014-P17NT  
 (PIN INSERT)  
 30 AMP, 250V AC  
 39 WIRE, 39 POLE

RECEPTACLE "C"-480V AC STATION POWER CABLE

RECEPTACLE



CROUSE HINDS  
 \*AR637 RECEPTACLE W/CAP  
 (SOCKET INSERT)  
 60 AMP, 600 V AC  
 3 WIRE, 3 POLE

CROUSE HINDS  
 \*AR637S22 RECEPTACLE W/CAP  
 (PIN INSERT)  
 60 AMP, 600V AC  
 3 WIRE, 3 POLE

RECEPTACLE "D"-120/240V AC STATION POWER CABLE

RECEPTACLE "J" CONTROL CABLE (ECW)

RECEPTACLE "S"

SAME AS RECEPTACLE "B"

SAME AS RE

| ZONE | LTR       |
|------|-----------|
| A    | SEE NEEDS |

END

SWITCHGEAR CONTROL UNIT END

ENGINE-GENERATOR UNIT END



TACLE  
AP

CROUSE HINDS  
 \*ARI04754/522 RECEPTACLE W/CAP  
 (PIN INSERT)  
 100 AMP, 600 V AC  
 4 POLE, 4 WIRE  
 (ROTATED 22.5°)

RECEPTACLE "F"-SHORE POWER CABLE



RECEPTACLE W/CAP

CROUSE HINDS  
 \*AR347 RECEPTACLE W/CAP  
 (SOCKET INSERT)  
 30 AMP, 600V AC  
 4 WIRE, 4 POLE



CROUSE HINDS  
 \*AR6347S22 RECEPTACLE W/CAP  
 (PIN INSERT)  
 30 AMP, 600 V AC  
 4 WIRE, 4 POLE

RECEPTACLE "G"-125 V DC POWER & EMER. LIGHTING CABLE



TACLE W/CAP

CROUSE HINDS  
 \*RPE233-014-P17NT RECEPTACLE W/CAP  
 (PIN INSERT)  
 30 AMP, 250V AC  
 39 WIRE, 39 POLE



CROUSE HINDS  
 \*RPE233-014-P17NT RECEPTACLE W/CAP  
 (PIN INSERT)  
 30 AMP, 250V AC  
 39 WIRE, 39 POLE

RECEPTACLE "H"-ANNUNCIATOR CABLE

W/CAP

RECEPTACLE "S" COMMUNICATIONS CABLE  
 SAME AS RECEPTACLE "B"

|         |       |                  |                         |                             |
|---------|-------|------------------|-------------------------|-----------------------------|
| 2       | 5U539 | RPE233-014-P17NT | RECEPTACLE              | CROUSE                      |
| 1       | 5U539 | AR6347S22        | RECEPTACLE              | CROUSE                      |
| 1       | 5U539 | AR347            | RECEPTACLE              | CROUSE                      |
| 1       | 5U539 | ARI04754/522     | RECEPTACLE              | CROUSE                      |
|         |       |                  | (REMOVED)               |                             |
|         |       |                  | (REMOVED)               |                             |
| 1       | 5U539 | AR6637S22        | RECEPTACLE              | CROUSE                      |
| 1       | 5U539 | AR637            | RECEPTACLE              | CROUSE                      |
| 1       | 5U539 | AR6648S22        | RECEPTACLE              | CROUSE                      |
| 1       | 5U539 | AR648            | RECEPTACLE              | CROUSE                      |
| 2       | 5U539 | RPE233-014-S17NT | RECEPTACLE              | CROUSE                      |
| 2       | 08051 | M5 25043-28D     | DUST CAP                | CANNON                      |
| 2       | 08051 | M5 3102R28-165   | RECEPTACLE              | CANNON                      |
| QTY/REQ |       | FROM NO.         | PART OR IDENTIFYING NO. | NOMENCLATURE OR DESCRIPTION |

DUEL FUEL 1500 KW  
 CONVERSION OF DIESEL POWER PLANTS  
 SATISFACTORY TO:  
 NAME: CHILDS  
 NORMAN HILGESSON DEC 1998

769-DF  
 PREPARED BY: [Signature]  
 REVIEWED BY: [Signature]  
 DRAWN BY: [Signature]  
 INSP BY: [Signature]  
 APPROVED BY: [Signature]  
 DATE: [Signature]  
 SCALE: F

ENGINE-GENERATOR UNIT END

CAP

IRE POWER CABLE



CROUSE HINDS  
#AR 6347S22 RECEPTACLE W/ CAP  
(PIN INSERT)  
30 AMP, 600V AC  
4 WIRE, 4 POLE

POWER & EMER. LIGHTING CABLE



CROUSE HINDS  
#RPE233-014-P17NT RECEPTACLE W/CAP  
(PIN INSERT)  
30 AMP, 250V AC  
39 WIRE, 39 POLE

DIATOR CABLE

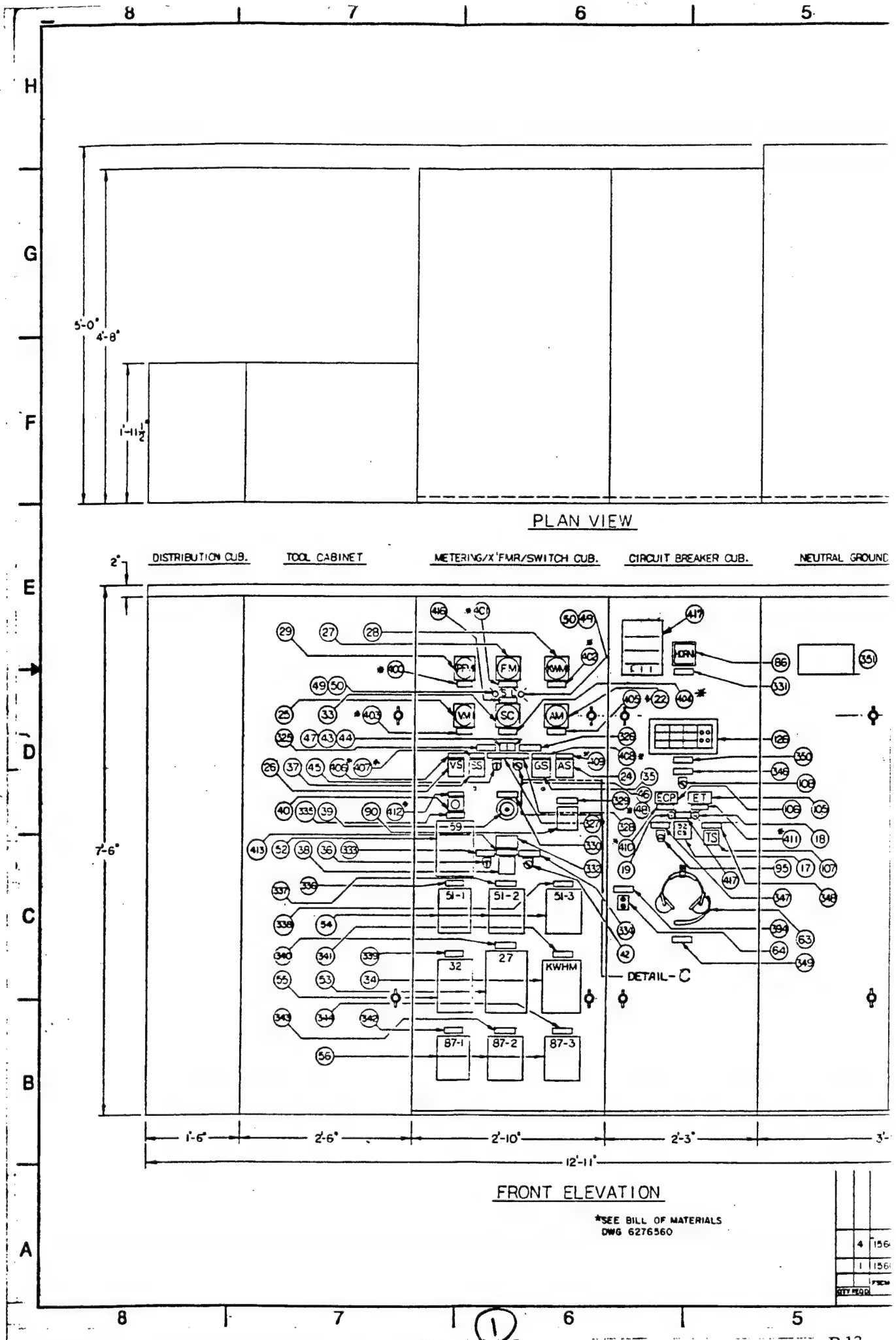
|     |        |                        |                             |                                         |          |
|-----|--------|------------------------|-----------------------------|-----------------------------------------|----------|
| 2   | 5U539  | RPE233-014-P17NT       | RECEPTACLE                  | CROUSE HINDS (39 WIRE, 39 POLE, MALE)   | 13       |
| 1   | 5U539  | AR 6347S22             | RECEPTACLE                  | CROUSE HINDS (4 WIRE, 4 POLE, MALE)     | 12       |
| 1   | 5U539  | AR 347                 | RECEPTACLE                  | CROUSE HINDS (4 WIRE, 4 POLE, FEMALE)   | 11       |
| 1   | 5U539  | AR104754522            | RECEPTACLE                  | CROUSE HINDS (4 WIRE, 4 POLE, MALE)     | 10       |
|     |        |                        | (REMOVED)                   |                                         | 9        |
|     |        |                        | (REMOVED)                   |                                         | 8        |
| 1   | 5U539  | AR6637S22              | RECEPTACLE                  | CROUSE HINDS (3 WIRE, 3 POLE, MALE)     | 7        |
| 1   | 5U539  | AR 637                 | RECEPTACLE                  | CROUSE HINDS (3 WIRE, 3 POLE, FEMALE)   | 6        |
| 1   | 5U539  | AR6648S22              | RECEPTACLE                  | CROUSE HINDS (3 WIRE, 4 POLE, MALE)     | 5        |
| 1   | 5U539  | AR 648                 | RECEPTACLE                  | CROUSE HINDS (3 WIRE, 4 POLE, FEMALE)   | 4        |
| 2   | 5U539  | RPE233-014-S17NT       | RECEPTACLE                  | CROUSE HINDS (39 WIRE, 39 POLE, FEMALE) | 3        |
| 2   | 08051  | MS 25043-28D           | DUST CAP                    | CANNON                                  | 2        |
| 2   | 08051  | MS 3102R28-169         | RECEPTACLE                  | CANNON (20 WIRE, 20 POLE, FEMALE)       | 1        |
| QTY | PCN NO | PART OR IDENTIFYING NO | NOMENCLATURE OR DESCRIPTION | MATERIAL SPECIFICATION                  | ITEM NO. |

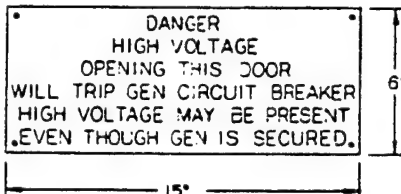
CATIONS CABLE

3"

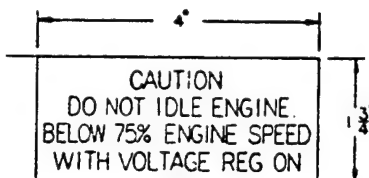
|                                                                |  |                  |  |                                                                                         |  |
|----------------------------------------------------------------|--|------------------|--|-----------------------------------------------------------------------------------------|--|
| DUEL FUEL 1500 KW<br>CONVERSION OF DIESEL POWER PLANTS         |  | 769-DF           |  | OVERHAUL 1500 KW<br>DIESEL POWER PLANTS<br>INTERCONNECTING CABLES<br>MATING RECEPTACLES |  |
| SATISFACTORY TO<br>BRIKE CHILDERS<br>NORMAN H. LILSON DEC-9994 |  | APPROVED<br>DATE |  | F 80091                                                                                 |  |
| SALE PRICE                                                     |  | DATE             |  | 6276556                                                                                 |  |
|                                                                |  | DATE             |  | 447408-89-C-2011                                                                        |  |
|                                                                |  | DATE             |  | 10                                                                                      |  |



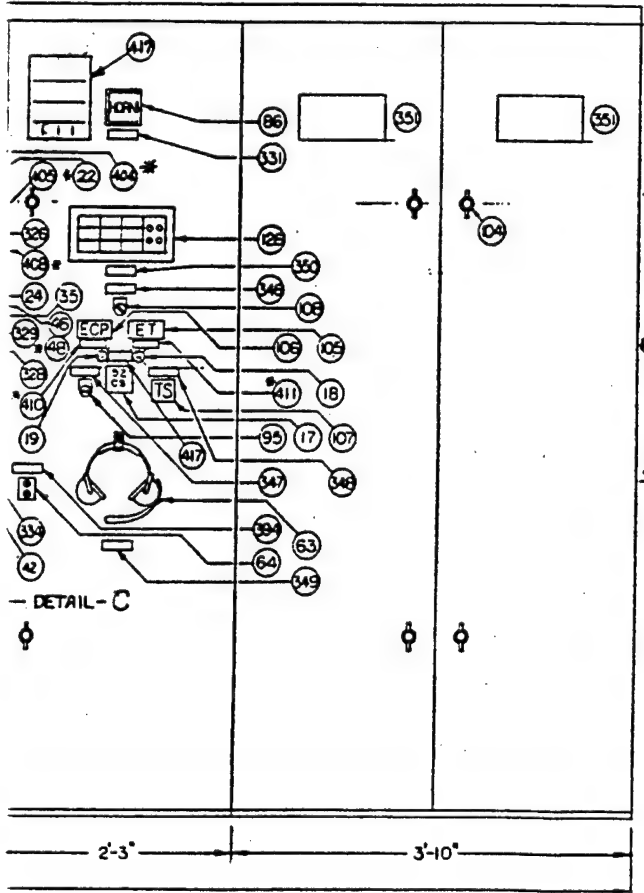




③ DETAIL-A SCALE: 1/2  
RED PHENOLIC WITH WHITE LETTERS  
1/2" LETTERS



332 DETAIL-B  
RED PHENOLIC WITH WHITE LETTERS  
1/4" LETTERS



— DETAIL - C —

DUAL FUEL STATUS LIGHTS,  
SELECTOR SWITCHES, AND  
LABELING PLATES - BLACK PHENOL WITH  
WHITE LETTERS

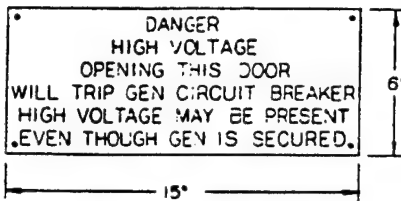
|    |                     |                   | GRS DETECTOR | SERRA MON      |
|----|---------------------|-------------------|--------------|----------------|
| 1  | ICA79 NAMEPLATE     | 1 X 3             | BLACK        | SYNCHRONIZ     |
| 1  | 6E0931JP-2          | JACK PLATE        |              | SOUND POWER    |
| 1  | ICA79 NAMEPLATE     | 1 X 3 1/2         | BLACK        | SOUND POWER    |
| 2  | ICA79 NAMEPLATE     | 6 X 15            | RED          | (SEE DETAIL)   |
| 1  | ICA79 NAMEPLATE     | 1 X 3 1/2         | BLACK        | ANNUNCIATOR    |
| 1  | ICA79 NAMEPLATE     | 1 X 3 1/2         | BLACK        | SMV CIRCUIT    |
| 1  | ICA79 NAMEPLATE     | 1 X 3 1/2         | BLACK        | ENGINE TEMP.   |
| 1  | ICA79 NAMEPLATE     | 1 X 3 1/2         | BLACK        | ENGINE STOP    |
| 1  | ICA79 NAMEPLATE     | 1 X 3 1/2         | BLACK        | EMERGENCY      |
| 1  | ICA79 NAMEPLATE     | 1 X 3 1/2         | BLACK        | ALARM HORN     |
| 2  |                     | PUSH-BTN SW       | C-H (NOINJ)  |                |
| 1  | ICA79 NAMEPLATE     | 1 X 3 1/2         | BLACK        | DIFFERENTIAL   |
| 1  | ICA79 NAMEPLATE     | 1 X 3 1/2         | BLACK        | DIFFERENTIAL   |
| 1  | ICA79 NAMEPLATE     | 1 X 3 1/2         | BLACK        | DIFFERENTIAL   |
| 1  | ICA79 NAMEPLATE     | 1 X 3 1/2         | BLACK        | KILZMATT -     |
| 1  | ICA79 NAMEPLATE     | 1 X 3 1/2         | BLACK        | LINGER VOLT    |
| 1  | ICA79 NAMEPLATE     | 1 X 3 1/2         | BLACK        | REVERSE PH     |
| 1  | ICA79 NAMEPLATE     | 1 X 3 1/2         | BLACK        | OVER CURR      |
| 1  | ICA79 NAMEPLATE     | 1 X 3 1/2         | BLACK        | OVER CURR      |
| 1  | ICA79 NAMEPLATE     | 1 X 3 1/2         | BLACK        | OVER CURR      |
| 1  | ICA79 NAMEPLATE     | 1 X 3 1/2         | BLACK        | OVER CURR      |
| 1  | ICA79 NAMEPLATE     | 1 X 3 1/2         | BLACK        | OVER CURR      |
| 1  | ICA79 NAMEPLATE     | 1 X 3 1/2         | BLACK        | UNIT PARAL     |
| 1  | ICA79 NAMEPLATE     | 1 X 3 1/2         | BLACK        | FREQUENCY      |
| 1  | ICA79 NAMEPLATE     | 1 3/4 X 4         | RED          | (SEE DETAIL)   |
| 1  | ICA79 NAMEPLATE     | 1 X 3 1/2         | BLACK        | MANUAL FIE     |
| 1  | ICA79 NAMEPLATE     | 1 X 3 1/2         | BLACK        | LOCKOUT REL    |
| 1  | ICA79 NAMEPLATE     | 1 X 3             | BLACK        | PHASE SEQ.     |
| 1  | ICA79 NAMEPLATE     | 1 X 3             | BLACK        | PHASE SEQ.     |
| 1  | ICA79 NAMEPLATE     | 1 X 3 1/2         | BLACK        | PHASE SEQ.     |
| 1  | ICA79 NAMEPLATE     | 1 X 3 1/2         | BLACK        | PHASE SEQ.     |
| 1  | 32582 TYPE-A NC CO  | ANNUNCIATOR       |              | ROCHESTER, AN  |
| 1  | 15605 0250T0K54     | SW, EMERG LTS     |              | CUTLER-HAMM    |
| 1  | 62806 SBMIQAAAC44   | SW, ENG. TEMP     |              | GE, TYPE-SBM   |
| 1  | 81045CE470000000    | METER, DGTL PNL   |              | LFE, MODEL 44B |
| 1  | 81045CE99940000     | METER, DGTL PNL   |              | LFE, MODEL 44A |
| 10 | 67978168-10-10      | TOE HANDLE        |              | SOUTH-CO, CH   |
| 1  | 15605 0250T0RS34    | ENGINE STOP PB    |              | CUTLER-HAMM    |
| 1  | 60336 1H2HEABIM2I   | RELAY, DEVICE 86  |              | PROTECTIVE     |
| 1  | 65063 1450          | HORN              |              | FEDERAL, 125V  |
| 3  | 62806 12LDJ52A11A   | RELAY, DEVICE-87  |              | GE, PROTECTIV  |
| 1  | 62806 12ICW51A1A    | RELAY, DEVICE-32  |              | GE, PROTECTIV  |
| 3  | 62806 12ICFV51ADIA  | RELAY, DEVICE-51  |              | GE, PROTECTIV  |
| 1  | 62806 12IAV54E1A    | RELAY, DEVICE-27  |              | GE, PROTECTIV  |
| 1  | 62802 12IAV51A1A    | RELAY, DEVICE-59  |              | GE, PROTECTIV  |
| 2  | 24455 6S6DC-125V    | LAMP, SYNC        |              | GE, LAMP, 125V |
| 2  | 96312 9-3205-035-30 | LIGHT, SYN        |              | DIALCO, 24V-   |
| 2  | 54837 BBJ22K5       | RES, 22.5KN.2W    |              | OHMMITE META   |
| 1  | 15605 10250T137I    | SW, 0 SEQ TEST    |              | CUTLER-HAMM    |
| 1  | 15605 10250T21K8    | SWITCH, 0 SEQ     |              | CUTLER-HAMM    |
| 2  | 62806 B7A (NE45)    | LAMP, NEON        |              | GE, T-4 1/2 SC |
| 2  | 62506 CRIO3C2102    | LIGHT, INDICATOR  |              | GE, TYPE CRIU  |
| 1  | 15605 10250T20KB    | SWITCH, PARALLEL  |              | CUTLER-HAMM    |
| 1  | 68513 06874         | RHEO, 500Ω-4W     |              | BASLER, AUT    |
| 1  | 54837 5105          | RHEOSTAT, FIELD   |              | OMRON, 75 Ω    |
| 1  | 62806 CJC295A12PI   | SW, VOLT REG      |              | GE, TYPE-SBM   |
| 1  | 62806 SBMIQAAO24    | SWITCH, SYNC      |              | GE, TYPE-SBM   |
| 1  | 15605 10250T21K8    | SWITCH, FREQ      |              | CUTLER-HAMM    |
| 1  | 62806 SBMIQAAOC5    | SWITCH, GOV       |              | GE, TYPE-SBM   |
| 1  | 60336 JCKX663G1     | KILOWATT-HOUR MTR |              | GE, TYPE-D5-   |
| 1  | 60336 50-048-52AAA  | SYNCHROSCOPE      |              | GE, TYPE-AB    |
| 6  | P/N IC20574100018   | LAMP SOCKETS      |              | CUTLER-HAMM    |
| 1  | 60336 50-048-52AAA  | POWER FACTOR MTR  |              | GE, TYPE-AB    |
| 1  | 60336 50-048-52AAA  | KILOWATT METER    |              | GE, TYPE-AB    |
| 1  | 60336 50-048-52AAA  | FREQUENCY MTR     |              | GE, TYPE-AB    |
| 1  | 62806 SBMIQAAO07    | SW, VOLTMETER     |              | GE, TYPE-SBM   |
| 1  | 60336 50-048-52AAA  | VOLTMETER         |              | GE, TYPE-AB    |
| 1  | 62806 SBMIQAAOC5    | SWITCH, AMMETER   |              | GE, TYPE-SBM   |
| 1  | 60336 50-048-52AAA  | AMMETER           |              | GE, TYPE-AB    |
| 1  | 62806 IC666CBG3-1   | LIGHT, GREEN      |              | GE, TYPE-ET-   |
| 1  | 62806 IC666CBG3-7   | LIGHT, RED        |              | GE, TYPE-ET-   |
| 1  | 62806 SBMIQAA10     | SW, CB CONTROL    |              | GE, TYPE-SBM   |

## ATION

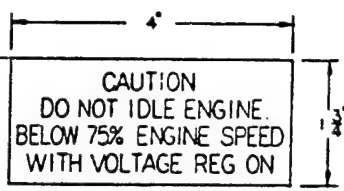
E BILL OF MATERIALS  
'G 6276560

[illegible]

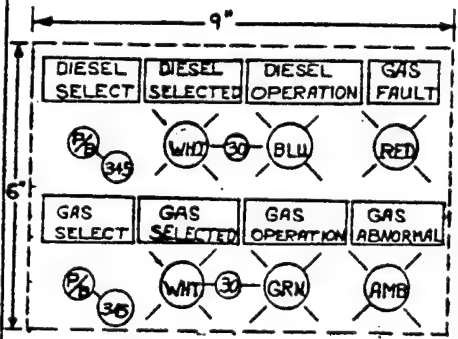
|                                                        |  |                                        |  |
|--------------------------------------------------------|--|----------------------------------------|--|
|                                                        |  | PARTS LIST                             |  |
|                                                        |  | 772-DF                                 |  |
| DUEL FUEL 1500 KW<br>CONVERSION OF DIESEL POWER PLANTS |  | DEPARTMENT OF THE<br>NAVAL ENGINEERING |  |
| SATISFACTORY TO<br>NAME COMPLIES                       |  | REVIEWED                               |  |
| HUGHMAN & LILSON                                       |  | CHECKED OUT                            |  |
| SATISFACTORY TO<br>NAME COMPLIES                       |  | REVIEWED                               |  |
| HUGHMAN & LILSON                                       |  | CHECKED OUT                            |  |
| SATISFACTORY TO<br>NAME COMPLIES                       |  | REVIEWED                               |  |
| HUGHMAN & LILSON                                       |  | CHECKED OUT                            |  |



35) **DETAIL-A** SCALE: 1/2  
RED PHENOLIC WITH WHITE LETTERS  
1/2" LETTERS



36) **DETAIL-B**  
RED PHENOLIC WITH WHITE LETTERS  
1/4" LETTERS



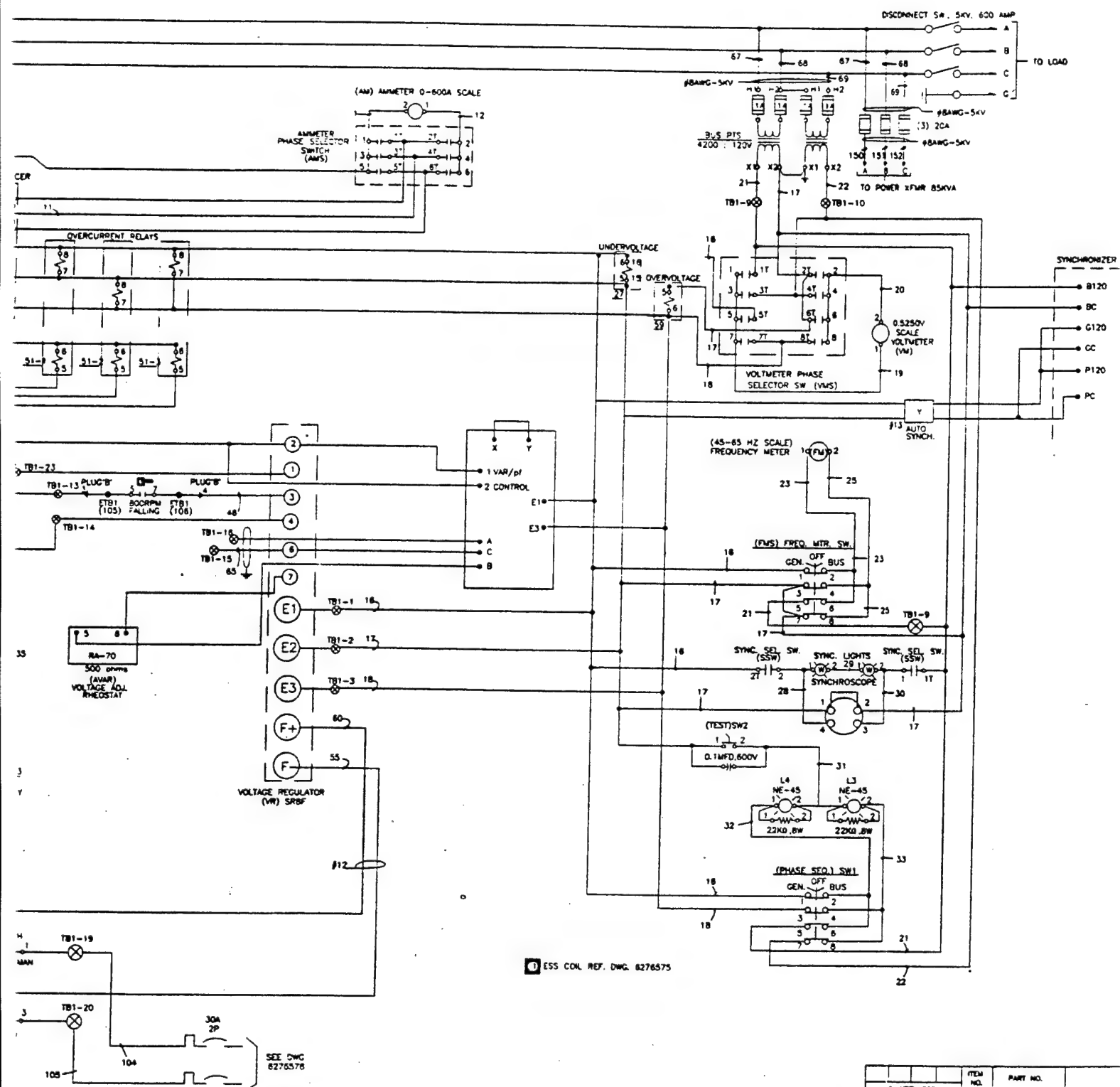
**DETAIL-C**  
DUAL FUEL STATUS LIGHTS,  
SELECTOR SWITCHES, AND  
LABELING PLATES - BLACK PHENOL WITH  
WHITE LETTERS

| REVISIONS            |                      |                                             |                                                 |                                       |    |
|----------------------|----------------------|---------------------------------------------|-------------------------------------------------|---------------------------------------|----|
| ZONE (LTR)           | DESCRIPTION          | DATE                                        | APPROVED                                        |                                       |    |
| A SEE MEESA DCN 92-6 |                      |                                             |                                                 |                                       |    |
| 1992-1-7             |                      |                                             |                                                 |                                       |    |
| 1                    | GRS DETECTOR         | SIERRA MONITOR CONTROLLER                   | 417                                             |                                       |    |
| 1                    | 1CA79 NAMEPLATE      | 1 X 3 BLACK SYNCHRONIZING / LIGHTS          | 416                                             |                                       |    |
| 1                    | 1560931JP-3          | JACK PLATE                                  | 64                                              |                                       |    |
| 1                    | 1CA79 NAMEPLATE      | 1 X 3 1/2 BLACK SOLNO POWER PHONE JACK      | 394                                             |                                       |    |
| 2                    | 1CA79 NAMEPLATE      | 6 X 15 RED (SEE DETAIL-A)                   | 351                                             |                                       |    |
| 1                    | 1CA79 NAMEPLATE      | 1 X 3 1/2 BLACK ANNUNCIATOR                 | 350                                             |                                       |    |
| 1                    | 1CA79 NAMEPLATE      | 1 X 3 1/2 BLACK 5KV CIRCUIT/BREAKER CUBICLE | 349                                             |                                       |    |
| 1                    | 1CA79 NAMEPLATE      | 1 X 3 1/2 BLACK ENGINE TEMP/OIL WATER       | 348                                             |                                       |    |
| 1                    | 1CA79 NAMEPLATE      | 1 X 3 1/2 BLACK ENGINE STOP                 | 347                                             |                                       |    |
| 1                    | 1CA79 NAMEPLATE      | 1 X 3 1/2 BLACK EMERGENCY LIGHTS / OFF ON   | 346                                             |                                       |    |
| 1                    | 1CA79 NAMEPLATE      | 1 X 3 1/2 BLACK ALARM HORN                  | 331                                             |                                       |    |
| 2                    | PUSH-BTN SW          | C-H (INDIC) P/N 10260T7910006               | 345                                             |                                       |    |
| 1                    | 1CA79 NAMEPLATE      | 1 X 3 1/2 BLACK DIFFERENTIAL / RELAY - 3    | 344                                             |                                       |    |
| 1                    | 1CA79 NAMEPLATE      | 1 X 3 1/2 BLACK DIFFERENTIAL / RELAY - 2    | 343                                             |                                       |    |
| 1                    | 1CA79 NAMEPLATE      | 1 X 3 1/2 BLACK DIFFERENTIAL / RELAY - 1    | 342                                             |                                       |    |
| 1                    | 1CA79 NAMEPLATE      | 1 X 3 1/2 BLACK KILOWATT HOUR / METER       | 341                                             |                                       |    |
| 1                    | 1CA79 NAMEPLATE      | 1 X 3 1/2 BLACK UNDER VOLTAGE / RELAY       | 340                                             |                                       |    |
| 1                    | 1CA79 NAMEPLATE      | 1 X 3 1/2 BLACK REVERSE POWER / RELAY       | 339                                             |                                       |    |
| 1                    | 1CA79 NAMEPLATE      | 1 X 3 1/2 BLACK OVER CURRENT / RELAY - 3    | 338                                             |                                       |    |
| 1                    | 1CA79 NAMEPLATE      | 1 X 3 1/2 BLACK OVER CURRENT / RELAY - 2    | 337                                             |                                       |    |
| 1                    | 1CA79 NAMEPLATE      | 1 X 3 1/2 BLACK OVER CURRENT / RELAY - 1    | 336                                             |                                       |    |
| 1                    | 1CA79 NAMEPLATE      | 1 X 3 1/2 BLACK OVER VOLTAGE / RELAY        | 335                                             |                                       |    |
| 1                    | 1CA79 NAMEPLATE      | 1 X 3 1/2 BLACK UNIT PARALLEL SWITCH        | 334                                             |                                       |    |
| 1                    | 1CA79 NAMEPLATE      | 1 X 3 1/2 BLACK FREQUENCY METER/SWITCH      | 333                                             |                                       |    |
| 1                    | 1CA79 NAMEPLATE      | 1 3/4 X 4 RED (SEE DETAIL-B)                | 332                                             |                                       |    |
| 1                    | 1CA79 NAMEPLATE      | 1 X 3 1/2 BLACK MANUAL FIELD/RHEOSTAT       | 330                                             |                                       |    |
| 1                    | 1CA79 NAMEPLATE      | 1 X 3 1/2 BLACK LOCKOUT RELAY               | 329                                             |                                       |    |
| 1                    | 1CA79 NAMEPLATE      | 1 X 3 BLACK PHASE SEQ. / TEST               | 328                                             |                                       |    |
| 1                    | 1CA79 NAMEPLATE      | 1 X 3 BLACK PHASE SEQ. / SELECT             | 327                                             |                                       |    |
| 1                    | 1CA79 NAMEPLATE      | 1 X 3 1/2 BLACK PHASE SEQ. / CBA            | 326                                             |                                       |    |
| 1                    | 1CA79 NAMEPLATE      | 1 X 3 1/2 BLACK PHASE SEQ. / ABC            | 325                                             |                                       |    |
| 1                    | 325821TYPE-AN3CO     | ANNUNCIATOR                                 | ROCHESTER, AN-300A-D4-INT9-3E-9-W-W-X-B-MOD-RMD | 126                                   |    |
| 1                    | 1560510250T20K542    | SW, EMERG LTS                               | CUTLER-HAMMER, 2PST, ON OFF LIGHTING            | 108                                   |    |
| 1                    | 1628061SBM10AAC44    | SW, ENG TEMP                                | GE, TYPE SBM, 4P, OIL - WATER                   | 107                                   |    |
| 1                    | 181045ICE-4T00-0000  | METER, DGTL PNL                             | LFE, MODEL 4443, 0-100 MV RANGE 100 PSIG        | 106                                   |    |
| 1                    | 181045CE-999-0000    | METER, DGTL PNL                             | LFE, MODEL 4443, RTD 100Ω, PLAT-200F+600F       | 105                                   |    |
| 10                   | 167978168-10-101-20  | TEE HANDLE                                  | SOUTH-CO. CHROME-PLATED HANDLE                  | 104                                   |    |
| 1                    | 1560510250T18534     | ENGINE STOP PB                              | CUTLER-HAMMER, OIL-TIGHT, 1 NC CONTACT          | 95                                    |    |
| 1                    | 160336112HE46M21     | RELAY, DEVICE 86                            | PROTECTIVE, LOCKOUT RELAY                       | 90                                    |    |
| 1                    | 150631450            | HORN                                        | FEDERAL, 125VDC VIBRATION HORN                  | 86                                    |    |
| 3                    | 162806121J052A11A    | RELAY, DEVICE-87                            | GE, PROTECTIVE DIFFERENTIAL RELAY               | 56                                    |    |
| 1                    | 162806121C515A1A     | RELAY, DEVICE-32                            | GE, PROTECTIVE REVERSE POWER RELAY              | 55                                    |    |
| 3                    | 162806121C515A1A     | RELAY, DEVICE-51                            | GE, PROTECTIVE OVERCURRENT RELAY                | 54                                    |    |
| 1                    | 162806121A534E1A     | RELAY, DEVICE-27                            | GE, PROTECTIVE UNDERVOLTAGE RELAY               | 53                                    |    |
| 1                    | 162802121A515A1A     | RELAY, DEVICE-59                            | GE, PROTECTIVE OVERVOLTAGE RELAY                | 52                                    |    |
| 2                    | 24455                | 6560C-125V                                  | LAMP, SYNC                                      | GE, LAMP, 125V, 6W, INCANDESCENT      | 50 |
| 2                    | 196312               | 9-32X05-3/32                                | LIGHT, SYNC                                     | DIALOOL, 24V-250V, CLEAR TORPEDO LENS | 49 |
| 2                    | 154837               | BBJ22K5                                     | RES, 22.5KΩ, 8W                                 | OHMITE META FILM RESISTOR             | 47 |
| 1                    | 1560510250T1371      | SW, 0 SEQ TEST                              | CUTLER-HAMMER, 2 POSITION, SPRING RET           | 46                                    |    |
| 1                    | 1560510250T21K8      | SWITCH, 0 SEQ                               | CUTLER-HAMMER, 3 POSITION, GEN-OFF-BUS          | 45                                    |    |
| 2                    | 1628061B7A (NE45)    | LAMP, NEON                                  | GE, T-4 1/2 SCREW BASE, 120VAC                  | 44                                    |    |
| 2                    | 1628061C103C2102     | LIGHT, INDICATOR                            | GE, TYPE C103C, PHASE SEQUENCE/IND              | 43                                    |    |
| 1                    | 1560510250T20K8      | SWITCH, PARALLEL                            | CUTLER-HAMMER, 2 POSITION, OILTIGHT             | 42                                    |    |
| 1                    | 168513               | 06874                                       | RHEO, 500Ω-4W                                   | BASLER, AUTOMATIC VOLTAGE/ADJUST      | 40 |
| 1                    | 154837               | 5105                                        | RHEOSTAT, FIELD                                 | OHMITE, 75Ω, 300 W                    | 39 |
| 1                    | 1628061C12951A2P1    | SW, VOLT REG                                | GE, TYPE-SBM, AUTO-MAN-OFF, SPECIAL             | 38                                    |    |
| 1                    | 1628061SBM10AAC024   | SWITCH, SYNC                                | GE, TYPE-SBM, W/ PNL 23W145 REM HOL             | 37                                    |    |
| 1                    | 1560510250T21K8      | SWITCH, FREQ                                | CUTLER-HAMMER, 3 POS, OT, GEN-OFF-BUS           | 36                                    |    |
| 1                    | 1628061SBM10AAC06    | SWITCH, GOV                                 | GE, TYPE-SBM, RAISE-LOWER, SPRING RET           | 35                                    |    |
| 1                    | 160335170CX63G1      | KILOWATT-HOUR MTR                           | GE, TYPE-DS-53, 2 ELEMENT, 3Ø, 3W               | 34                                    |    |
| 1                    | 160335150-06-42-4444 | SYNCH-ROSCCPE                               | GE, TYPE-AB-40, 60 HZ, SLOW-FAST SCALE          | 33                                    |    |
| 6                    | P/N 10250T7910006    | LAMP SOCKETS                                | CUTLER-HAMMER AC/DC REGIST, 120V                | 30                                    |    |
| 1                    | 160335150-06-42-4444 | POWER FACTOR MTR                            | GE, TYPE-AB-40, .5-1.5 SCALE, 120V COIL         | 29                                    |    |
| 1                    | 160335150-06-42-4444 | KILOWATT METER                              | GE, TYPE-AB-40, 0-2500KW, 3Ø, 3W                | 28                                    |    |
| 1                    | 160335150-06-42-4444 | FREQUENCY MTR                               | GE, TYPE-AB-40, .45-65HZ SCALE, 120V COIL       | 27                                    |    |
| 1                    | 1628061SBM10AAC071SW | SW, VOLTMETER                               | GE, TYPE-SBM, KNURLED HANDLE, VMSW              | 26                                    |    |
| 1                    | 160335150-03-021P1L  | VOLTMETER                                   | GE, TYPE-AB-40, 0-5250V SCALE, 150V COIL        | 25                                    |    |
| 1                    | 1628061SBM10AAC06    | SWITCH, AMMETER                             | GE, TYPE-SBM, KNURLED HANDLE, AMSW              | 24                                    |    |
| 1                    | 160335150-03-13H53   | AMMETER                                     | GE, TYPE-AB-40, 0-600A SCALE, 5A COIL           | 22                                    |    |
| 1                    | 1628061C666708G3-C   | LIGHT, GREEN                                | GE, TYPE-ET-6, W/ ET16G CAP                     | 19                                    |    |
| 1                    | 1628061C666708G3-P   | LIGHT, RED                                  | GE, TYPE-ET-6, W/ ET16G CAP                     | 18                                    |    |
| 1                    | 1628061SBM10AAC107   | ISW, CB CONTROL                             | GE, TYPE-SBM, PISTOL GRIP HANDLE, 52CS          | 17                                    |    |

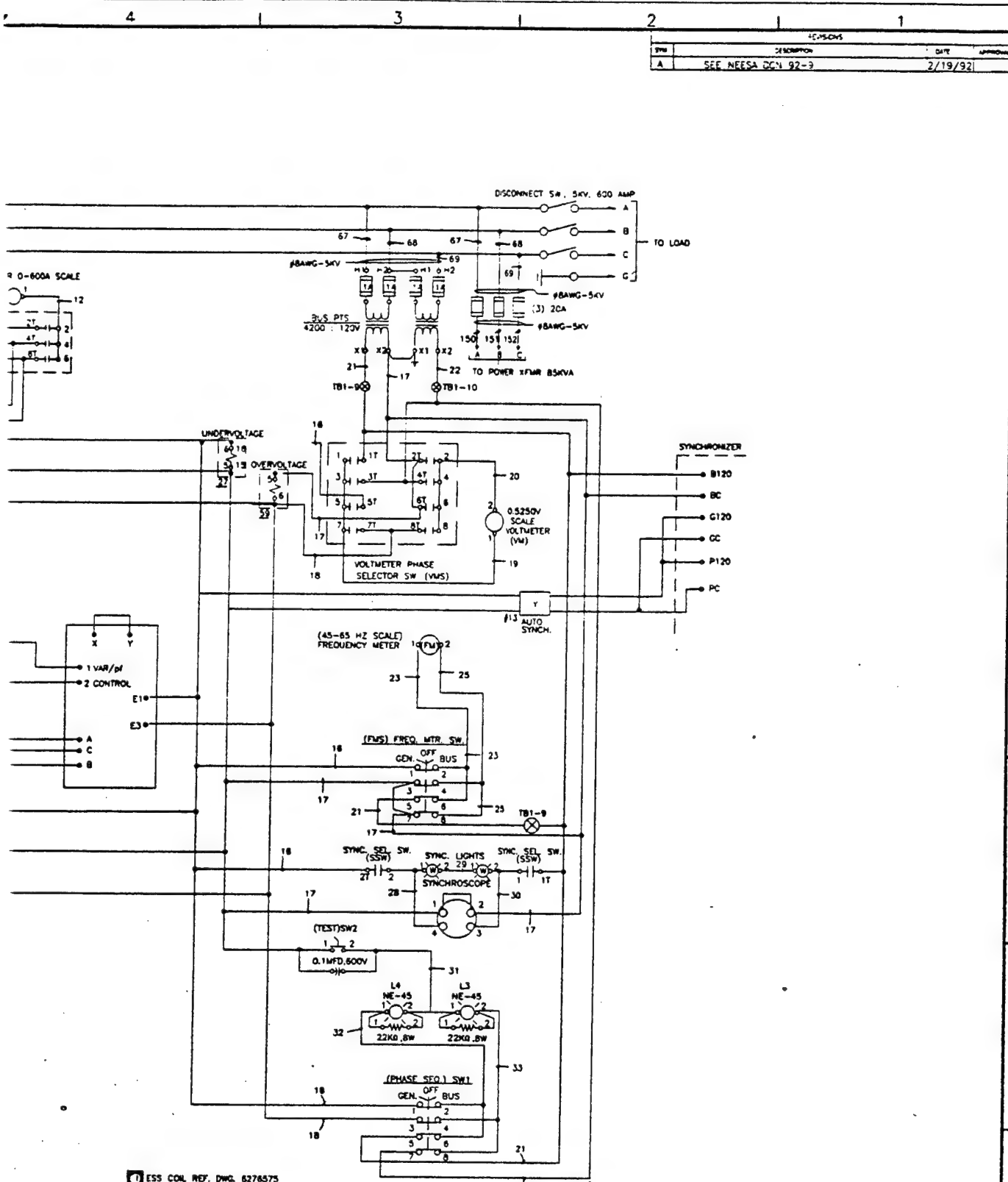
|                                                                            |          |                         |                                |            |                        |          |
|----------------------------------------------------------------------------|----------|-------------------------|--------------------------------|------------|------------------------|----------|
| SYN-REC'D                                                                  | PSCH NO. | PART OR IDENTIFYING NO. | NON-CONFORMANCE OR DESCRIPTION | PARTS LIST | MATERIAL SPECIFICATION | ITEM NO. |
| 772-DF                                                                     |          |                         |                                |            |                        |          |
| OVERHAUL 1500 KW DIESEL POWER PLANTS SWITCHGEAR LINE-UP PLAN AND ELEVATION |          |                         |                                |            |                        |          |
| F 80091                                                                    |          |                         |                                |            |                        |          |
| 6276559                                                                    |          |                         |                                |            |                        |          |
| N47408-99-C-2011                                                           |          |                         |                                |            |                        |          |
| 1/8                                                                        |          |                         |                                |            |                        |          |
| 13 of                                                                      |          |                         |                                |            |                        |          |

|                           |                                                                    |          |
|---------------------------|--------------------------------------------------------------------|----------|
| MEPLATE                   | UNIT PARALLEL AND PHASE SEQUENCE TEST FREQUENCY AND PHASE SEQUENCE | 128      |
| VTACT BLOCK               | CONTACT BLOCK USED WITH ITEM 46                                    | 127      |
| CONVENTION OR DESCRIPTION | INTERNAL/SPECIFICATION                                             | ITEM NO. |
| PARTS LIST                |                                                                    |          |





|                                                                     |  |                         |          |
|---------------------------------------------------------------------|--|-------------------------|----------|
| QUANTITY FOR EACH ASSEMBLY                                          |  | ITEM NO.                | PART NO. |
| UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES AND/OR DECIMALS |  | 780 - DF                |          |
| TOLERANCES:                                                         |  | OR F. OLLAUBER          |          |
| .XX DECIMALS                                                        |  | BRANCH HEAD R. MACK     |          |
| .XXX DECIMALS                                                       |  | DW DR                   |          |
| .0001 DECIMALS                                                      |  | SATISFACTORY TO         |          |
| FRACTIONS $\pm 1/16$                                                |  | WAKE CHILDERS           |          |
| ANGLES $\pm 0.5^\circ$                                              |  | NORMAN REEDSON DEC 1958 |          |
| PART DASH NO.                                                       |  | APPROVED                | DATE     |
| NEXT ASSY.                                                          |  | COMMANDING OFFICER      | DATE     |
|                                                                     |  | FOR COMMANDER, NAIFAC   | SCALE    |



ESS COIL REF. DWG. 6276575

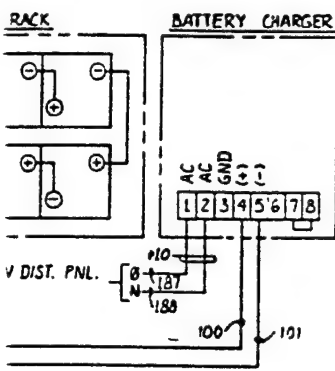
| QUANTITY FOR EACH ASSEMBLY                                                                                                                                     |  | ITEM NO.                                                                                                                                                                                                                                                                                                      | PART NO. | DESCRIPTION | MATERIAL |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------|--|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------|-------------|----------|
| UNLESS OTHERWISE SPECIFIED<br>DIMENSIONS ARE IN INCHES AND/OR DECIMALS                                                                                         |  | <p>PROJ. NO. 780 - DF</p> <p>DES. BY [Signature]</p> <p>CHK. BY [Signature]</p> <p>BRANCH HEAD &amp; CHECK [Signature]</p> <p>DATE [Date]</p> <p>APPROVED [Signature]</p> <p>COMMANDING OFFICER [Signature]</p> <p>FOR COMMANDER, NAVFAC</p>                                                                  |          |             |          |
| <p>TOLERANCES:</p> <p>.X DECIMALS</p> <p>.XX DECIMALS</p> <p>.XXX DECIMALS</p> <p>FRACTIONS <math>\pm 1/16</math></p> <p>ANGLES <math>\pm 0.5^\circ</math></p> |  | <p>DEPARTMENT OF THE NAVY</p> <p>NAVAL FACILITIES ENGINEERING SERVICE CENTER</p> <p>PORT HUENEME, CALIFORNIA 93043</p> <p>DUEL FUEL 1500 KW</p> <p>CONVERSION OF DIESEL POWER PLANTS</p> <p>SCHEMATIC DIAGRAM AC GENERATOR</p> <p>NAVJAC DRAWING NO. F 80091</p> <p>CONVERT CONTR NO.</p> <p>SHEET 1 OF 1</p> |          |             |          |

IF IN DOUBT, ASK - DO NOT SCALE

3







IS CKT.

OVERCURRENT RELAYING  
GE TYPE 12IFCV51A1A

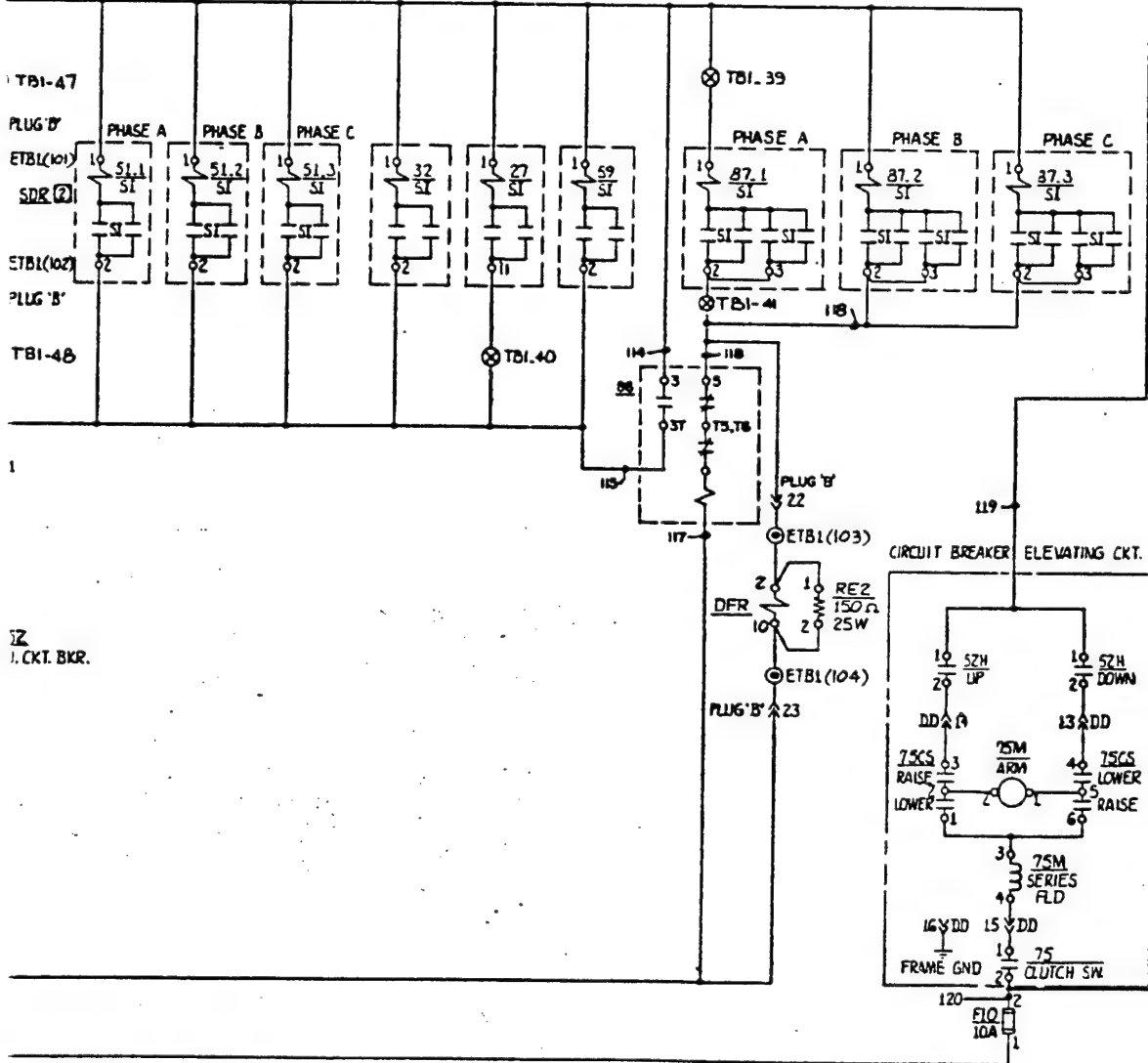
REVERSE  
PWR RELAY  
GE TYPE  
12ICW51A1A

UNDERVOLT-  
AGE RELAY  
GE TYPE  
12IAV54E1A

OVERVOLT-  
AGE RELAY  
GE TYPE  
12IAV51A1A

DIFFERENTIAL RELAYING  
GE TYPE 12IJD52A11A

RA-70 CONTROLS



575

75

DFR

2 10

3 1 4

(DWG. 6276575)

7 6 5

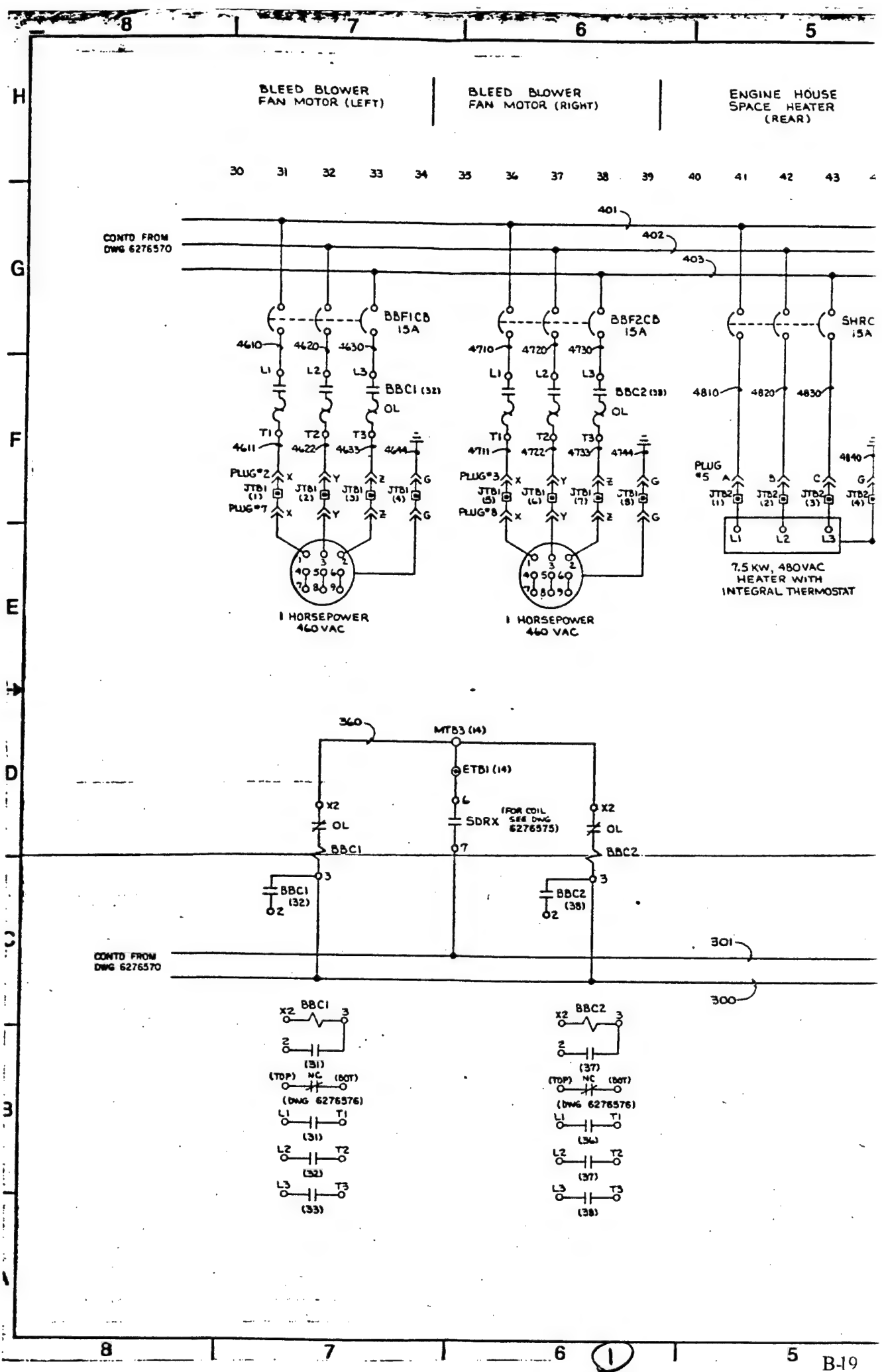
(DWG. 6276576)

9 11 8

|                   |         |                                   |    |
|-------------------|---------|-----------------------------------|----|
| DATE              | 7/20/60 | PART OR IDENTIFYING NO.           | 78 |
| REVISION          |         | DESCRIPTION                       |    |
| DUEL FUEL 1500 KW |         | CONVERSION OF DIESEL POWER PLANTS |    |
| SATISFACTORY TO   |         | DATE                              |    |
| W. H. CHILDS      |         | 7/20/60                           |    |
| NORMAN HILLMAN    |         | 7/20/60                           |    |
| W. H. CHILDS      |         | 7/20/60                           |    |









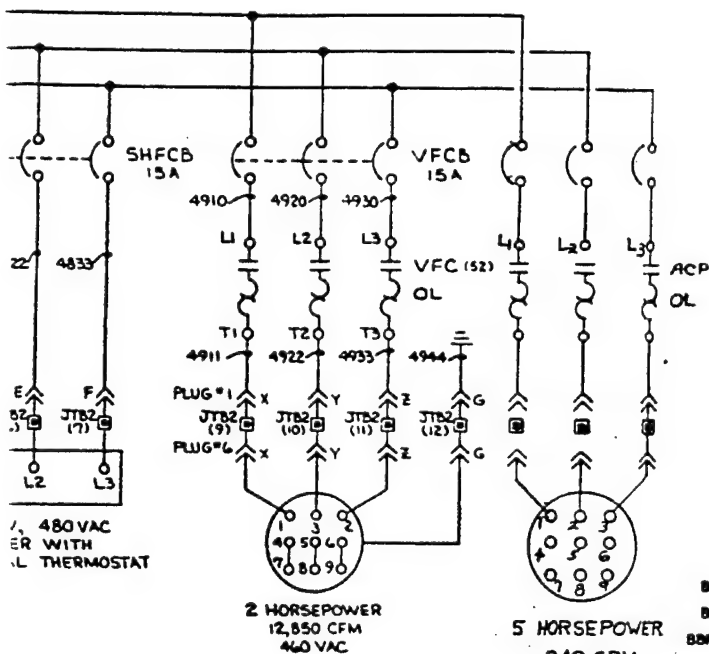
ENGINE HOUSE  
SPACE HEATER  
(FRONT)

ENGINE HOUSE  
ROOF MOUNTED  
EXHAUST FAN

AFTER COOLER  
PUMP MOTOR

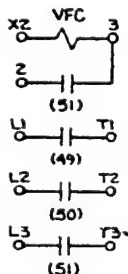
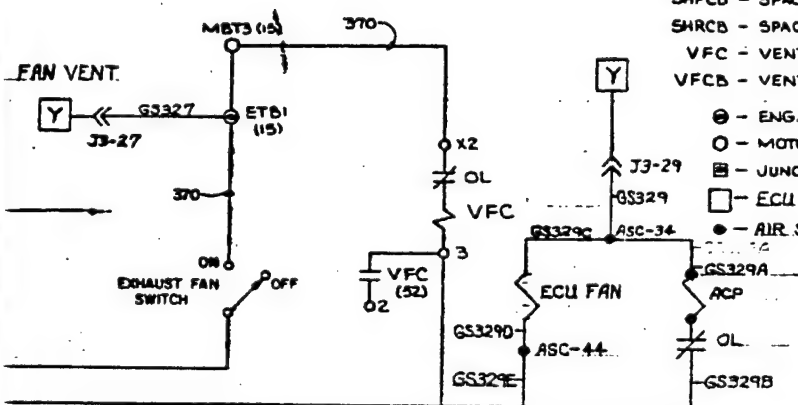
| REVISIONS |     |                      |           |
|-----------|-----|----------------------|-----------|
| ZONE      | LTR | DESCRIPTION          | DATE      |
| A         |     | SEE NEESA DCN 89-36. | 1989-6-2  |
| B         |     | SEE NEESA DCN 92-20  | 1992-2-19 |

46 47 48 49 50 51 52



#### LEGEND

- BB1 - BLEED BLOWER CONTROLLER
- BB2 - BLEED BLOWER CONTROLLER
- BBFCB - BLEED BLOWER FAN CIRCUIT BREAKER
- BBFCB - BLEED BLOWER FAN CIRCUIT BREAKER
- OL - OVERLOAD ELEMENT OR INTERLOCK
- SDRX - SHUTDOWN RELAY, AUXILIARY
- SHFCB - SPACE HEATER FRONT CIRCUIT BREAKER
- SHRCB - SPACE HEATER REAR CIRCUIT BREAKER
- VFC - VENTILATING FAN CONTROLLER
- VFCB - VENTILATING FAN CIRCUIT BREAKER
- ⊖ - ENG. CONTROL PANEL TERMINAL BLOCK
- - MOTOR CONTROL CENTER TERMINAL BLOCK
- ⊞ - JUNCTION BOX TERMINAL BLOCK
- - ECU OUTPUT, 130 VOLT DC
- - AIR SERVICE CABINET TERMINAL BLOCK



|                                                        |                         |                                                                                        |                        |          |
|--------------------------------------------------------|-------------------------|----------------------------------------------------------------------------------------|------------------------|----------|
| FROM NO                                                | PART OR IDENTIFYING NO. | NOMENCLATURE OR DESCRIPTION                                                            | MATERIAL/SPECIFICATION | ITEM NO. |
| PARTS LIST                                             |                         |                                                                                        |                        |          |
| 784                                                    |                         | NAVAL ENERGY AND ENVIRONMENTAL SUPPORT ACTIVITY<br>PERRY HARBOR, CALIFORNIA 92043-1004 |                        |          |
| DUEL FUEL 1500 KW<br>COMMISSION OF DIESEL POWER PLANTS |                         | OVERHAUL 1500 KW<br>DIESEL POWER PLANTS<br>SCHEMATIC DIAGRAM<br>MOTOR CONTROL CIRCUITS |                        |          |
| SATISFACTION TO<br>NORMAN HILGESON<br>DATE: 1994       |                         | DATE: 1994                                                                             |                        |          |
| APPROVED BY: [Signature]                               |                         | APPROVED BY: [Signature]                                                               |                        |          |
| F 80091                                                |                         | 6276571                                                                                |                        |          |
| NONE                                                   |                         | NONE                                                                                   |                        |          |



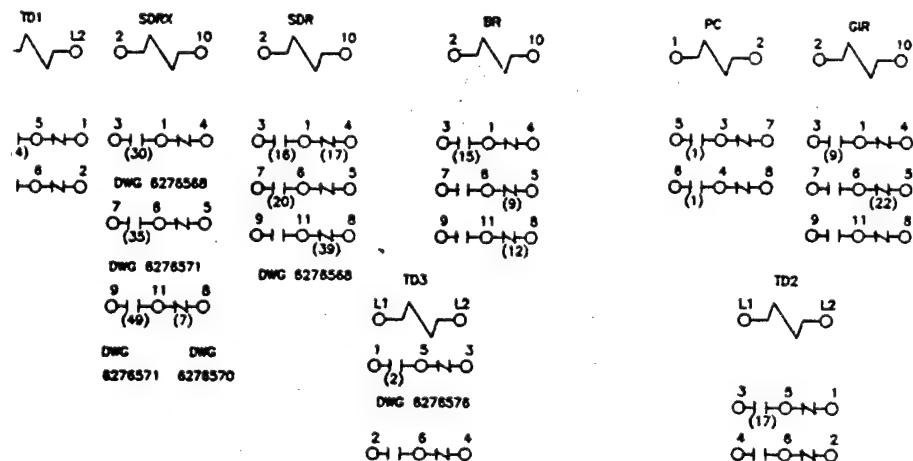
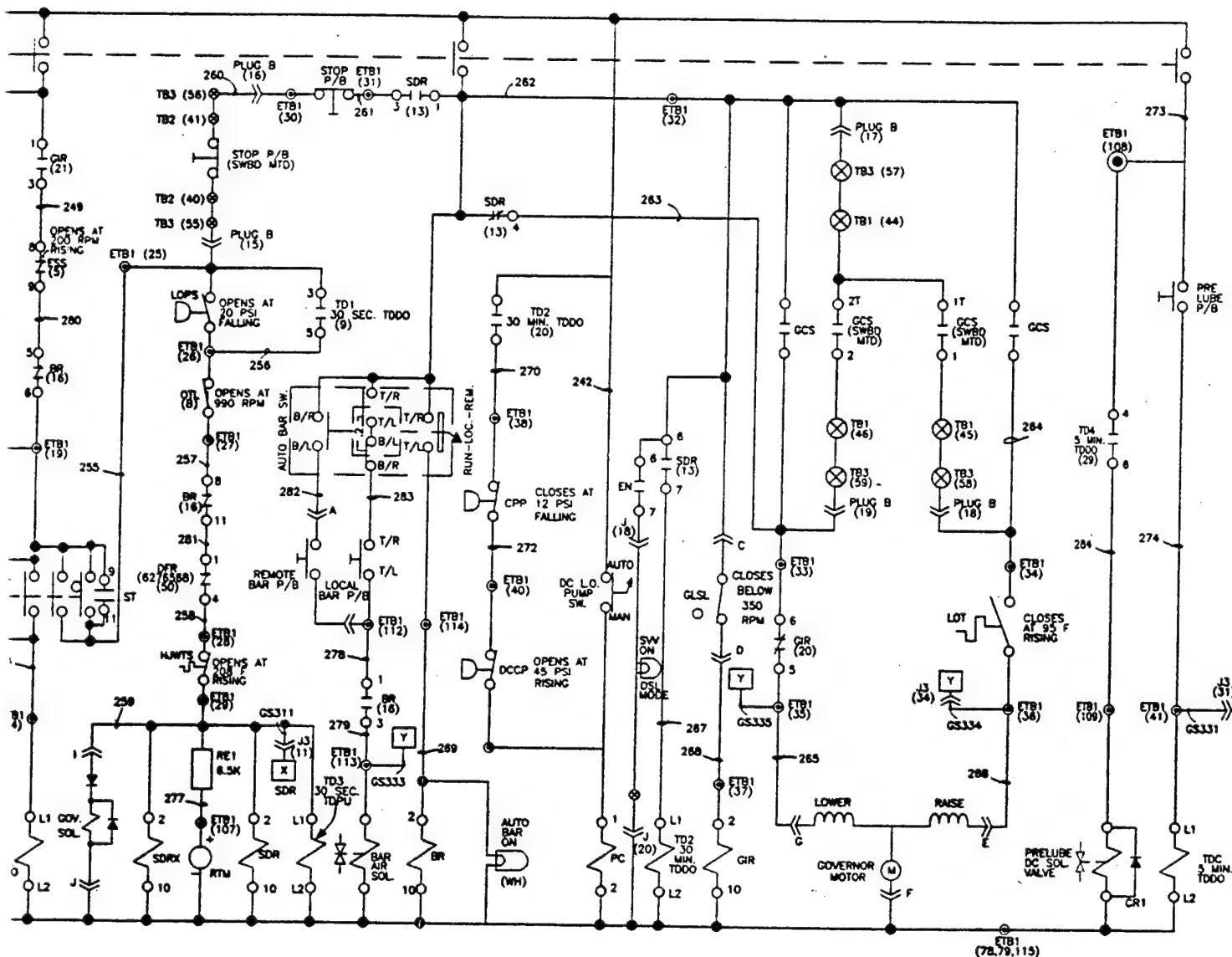
START / STOP CIRCUIT

AUTO ENG. BARRING

D.C. LUBE OIL PUMP CONTROL

GOVERNOR CONTROL CIRCUIT  
LIMIT START LOWER RAISE

ENGINE  
PRELUDE

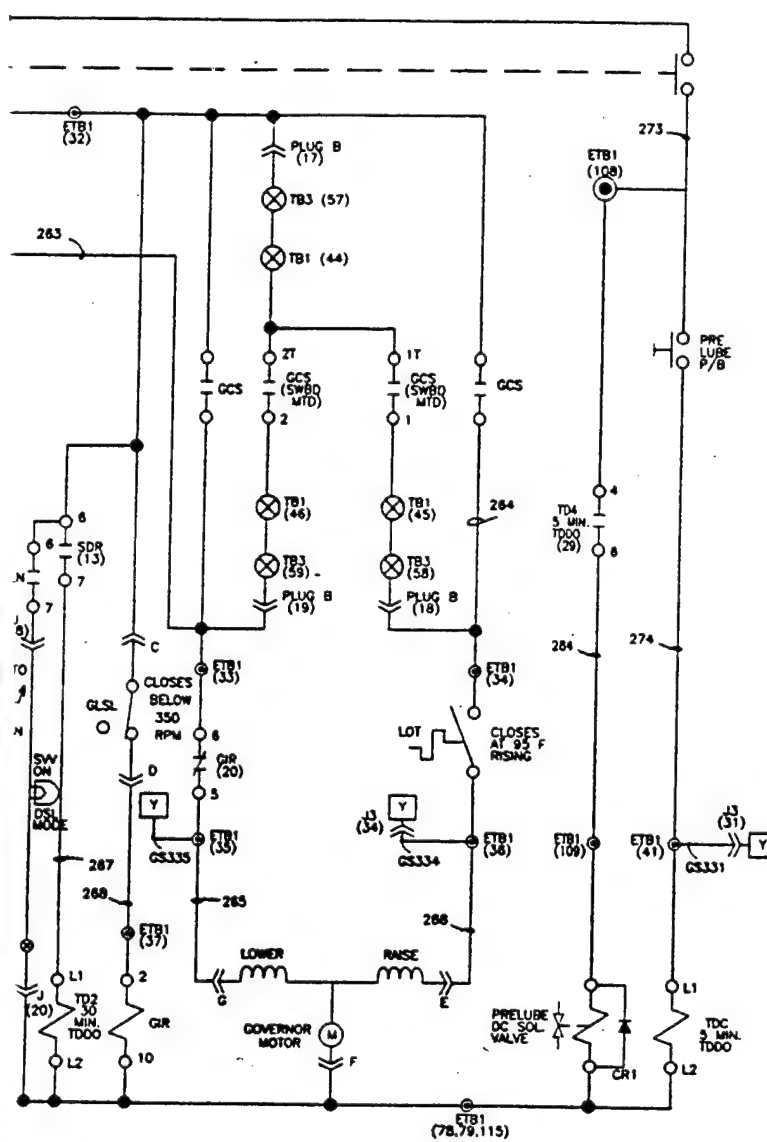


| DECK | CONTRACT | POSITION |     |       | LOCATION |
|------|----------|----------|-----|-------|----------|
|      |          | LOWER    | OFF | RAISE |          |
| 1    | N.O. TOP | X        |     |       | (22)     |
|      | N.O. BOT |          |     | X     | (26)     |

|                                                              |                        |          |
|--------------------------------------------------------------|------------------------|----------|
| QUANTITY FOR EACH ASSEMBLY                                   | ITEM NO.               | PART NO. |
| UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN FEET AND INCHES |                        |          |
| TOLERANCES:                                                  | DWG. NO. 788 - [ ]     |          |
| .X DECIMALS                                                  | DES. BY [ ]            |          |
| .XX DECIMALS                                                 | CHECKED BY [ ]         |          |
| .XXX DECIMALS                                                | DRAWN BY [ ]           |          |
| FRACTIONS 1/16"                                              | SATISFACTORY TO [ ]    |          |
| ANGLES ±0.5°                                                 | APPROVED BY [ ]        |          |
| PART NO.                                                     | COMMANDING OFFICER [ ] |          |
| NEXT ASSY.                                                   | APPROVED BY [ ]        |          |
|                                                              | FOR COMMANDER, B-21    |          |

IF IN DOUBT, ASK - DO NOT SCALE

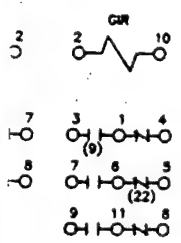
| REV | DESCRIPTION         | DATE    | APPROVAL |
|-----|---------------------|---------|----------|
| A   | SEE NEESA DCM 92-11 | 11/7/92 |          |



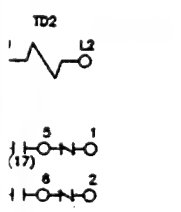
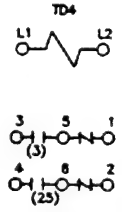
LEGEND

- BR - BARRING RELAY
- CPP - CIRCULATING PUMP PRESSURE SWITCH
- CR1 - CONTROL RECTIFIER
- DCCP - D.C. CIRCULATING PUMP SWITCH
- DFR - DIFFERENTIAL FAULT RELAY
- GCS - GOVERNOR CONTROL SWITCH
- GIR - GOVERNOR IDLE RELAY
- GLSL - GOVERNOR LIMIT SWITCH - LOW
- HJWTS - HIGH JACKET WATER TEMP. SHUTDOWN
- LOPS - LOW OIL PRESSURE SHUTDOWN
- LOT - LOW OIL TEMPERATURE SWITCH
- LSOP - LOW STANDBY OIL PRESSURE
- OTL - OVERSPEED TRIP LIMIT SWITCH
- PC - PUMP CONTROLLER
- RES - RESISTOR
- RTM - RUNNING TIME, METER
- SDR - SHUTDOWN RELAY
- SDRX - SHUTDOWN RELAY, AUXILIARY
- TD1 - TIME DELAY RELAY
- TD2 - TIME DELAY RELAY
- TD3 - TIME DELAY RELAY
- TD4 - TIME DELAY RELAY
- ER - ENGINE RUN
- ETB1 - ENG. TERMINAL BOARD NO. 1
- GSPS - GAS SYSTEM POWER SW.
- ST - STAYTIME RELAY
- X - ECU INPUT
- Y - ECU OUTPUT 130V DC

| OPERATING POINTS |       |      |
|------------------|-------|------|
| SWITCH           | CLOSE | OPEN |
| PRESSURE P.S.I.  |       |      |
| CPP              | 12    | 15   |
| DCCP             | 35    | 45   |
| LOPS             | 30    | 20   |
| LSOP             | 15    | 12   |
| TEMPERATURE      |       |      |
| HJWTS            | 198   | 208  |
| LOT              | 95    | 85   |



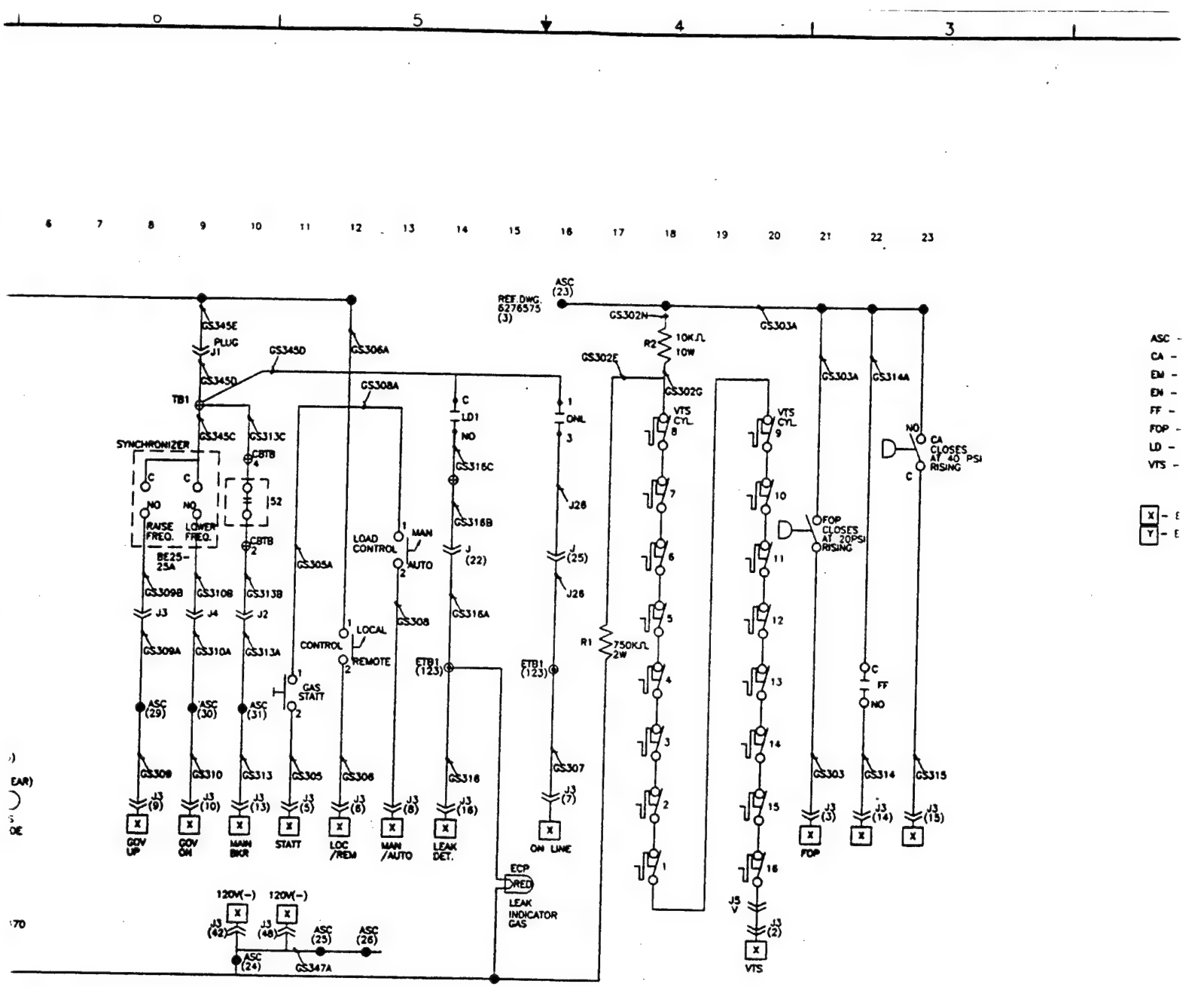
| DECK | CONTRACT  | POSITION |     |       | LOCATION |
|------|-----------|----------|-----|-------|----------|
|      |           | LOWER    | OFF | RAISE |          |
| 1    | N.O. TOP  | X        |     |       | (22)     |
|      | N.O. BOT. |          |     | X     | (28)     |



| QUANTITY FOR EACH ASSEMBLY                                                                                                 |            | ITEM NO.                                                                                                                                                  | PART NO. | DESCRIPTION  | MATERIAL |
|----------------------------------------------------------------------------------------------------------------------------|------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------|----------|--------------|----------|
| UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN FEET AND INCHES                                                               |            | <p>788 - DF</p> <p>CONV. OF DIESEL POWER PLANTS SCHEMATIC DIAGRAM ENGINE CONTROL CIRCUITS</p>                                                             |          |              |          |
| <p>TOLERANCES:</p> <p>.1 DECIMALS</p> <p>.01 DECIMALS</p> <p>.001 DECIMALS</p> <p>FRACTIONS ±1/16"</p> <p>ANGLES ±0.5°</p> |            | <p>APPROVED: [Signature] DATE: [Date]</p> <p>DESIGNED: [Signature] DATE: [Date]</p> <p>CHECKED: [Signature] DATE: [Date]</p> <p>FOR COMMANDER, NAJFAC</p> |          |              |          |
| PART NO.                                                                                                                   | NEXT ASSY. | F 80091                                                                                                                                                   |          | SHEET 1 OF 1 |          |







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OE

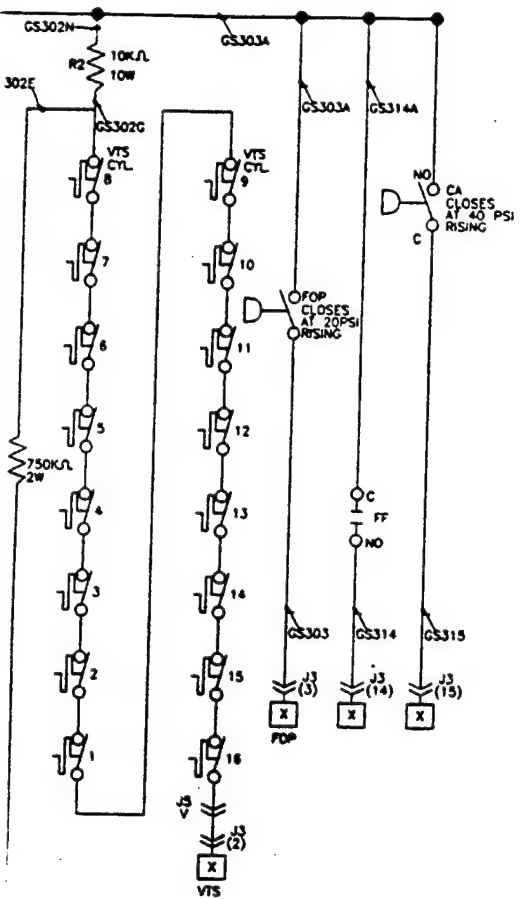
170

| QUANTITY FOR EACH ASSEMBLY                                      |            | ITEM NO.                   | P. |
|-----------------------------------------------------------------|------------|----------------------------|----|
| UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN FEET AND/OR INCHES |            | PROD. NO.                  |    |
| TOLERANCES:                                                     |            | DWG. NO.                   |    |
| .X DECIMALS                                                     |            | DWG. XX                    |    |
| .XX DECIMALS                                                    |            | CHG. XX                    |    |
| .XXX DECIMALS                                                   |            | BRANCH HEAD                |    |
| FRACTIONS                                                       |            | LOW CH                     |    |
| ANGLES                                                          |            | SATISFACTORY TO            |    |
|                                                                 |            | UNLESS OTHERWISE SPECIFIED |    |
|                                                                 |            | APPROVED                   |    |
|                                                                 |            | FOR COMMANDER              |    |
| PART DISH NO.                                                   | NEXT ASSY. |                            |    |

4 1 3 1 2 1 1

17 18 19 20 21 22 23

| REVISIONS |             |      |          |
|-----------|-------------|------|----------|
| REV       | DESCRIPTION | DATE | APPROVAL |
|           |             |      |          |



**LEGEND**

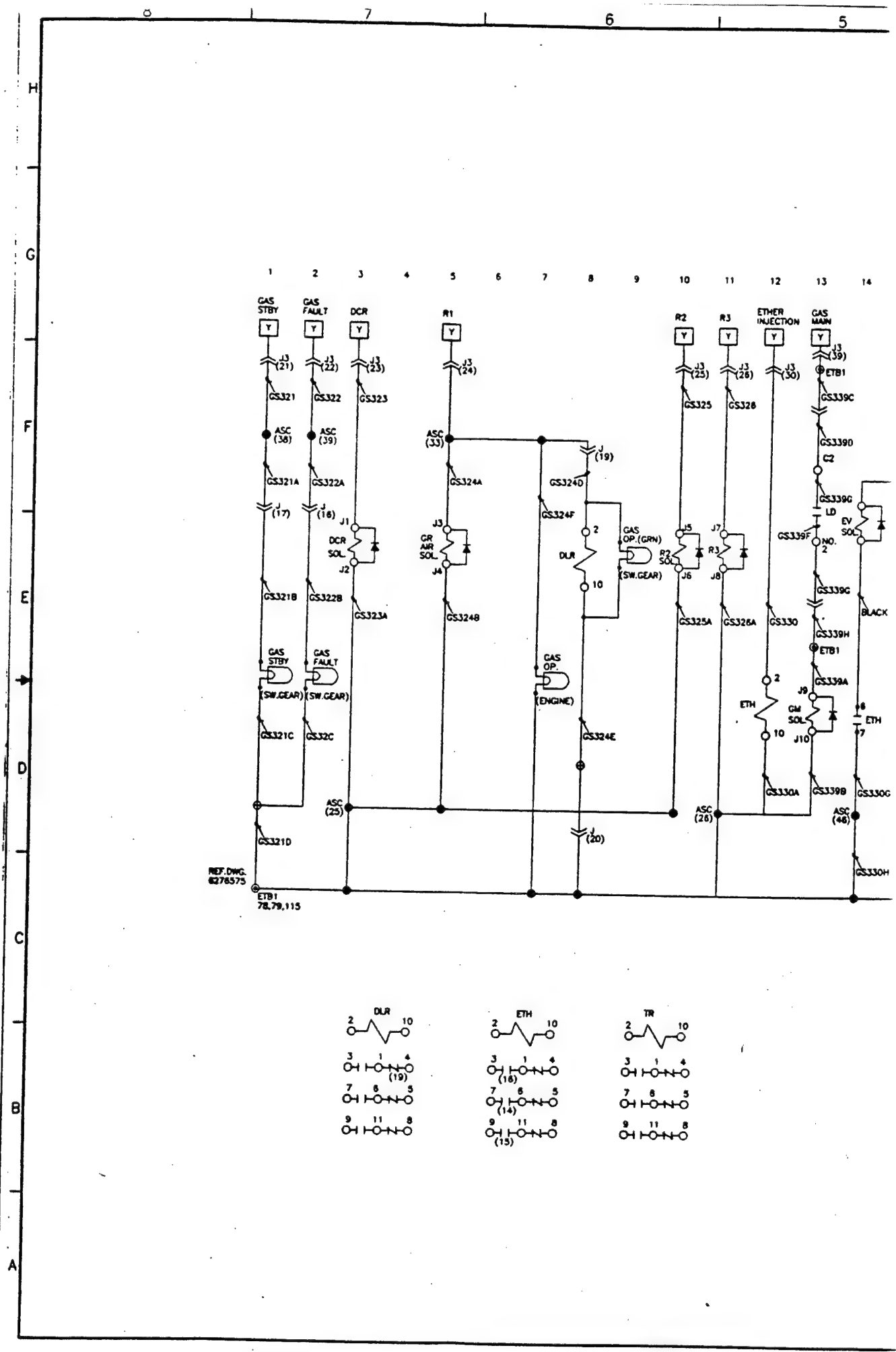
ASC - AIR SERVICE CAB  
 CA - COLD AIR SIGNAL  
 EM - ENGINE MODE SW.  
 EN - ENABLE GAS RELAY  
 FF - FAN FLOW SIGNAL  
 FOP - FUEL OIL PRESSURE  
 LD - LEAK DETECTION SIGNAL  
 VTS - VALVE TEMPERATURE SW.

X - ECU INPUT  
 Y - ECU OUTPUT 130V DC

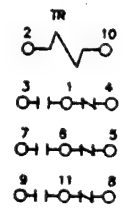
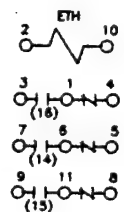
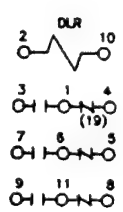
IF IN DOUBT, ASK - DO NOT SCALE

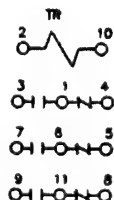
|                                                                                                                   |  |                                                                                                                                                                                                                                                                                                                   |          |             |          |
|-------------------------------------------------------------------------------------------------------------------|--|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------|-------------|----------|
| QUANTITY FOR EACH ASSEMBLY                                                                                        |  | ITEM NO.                                                                                                                                                                                                                                                                                                          | PART NO. | DESCRIPTION | MATERIAL |
| UNLESS OTHERWISE SPECIFIED<br>DIMENSIONS ARE IN FEET AND/OR INCHES                                                |  | PROJ NO<br>DES NO <b>788A-DF</b><br>DES XX <b>1017 DELTA/REDA</b><br>DES XX<br>BRANCH HEAD H. BACK<br>SW OR<br>BATTERY FACTORY TO<br>WIRE CHANGES<br>APPROVED <b>NOV 1958</b><br>COMMANDING OFFICER<br>APPROVED<br>FOR COMMANDER, NAVFAC                                                                          |          |             |          |
| TOLERANCES:<br>.12 DECIMALS<br>.002 DECIMALS<br>.0002 DECIMALS<br>FRACTIONS $\pm 1/16"$<br>ANGLES $\pm 0.5^\circ$ |  | DEPARTMENT OF THE NAVY<br>NAVAL FACILITIES ENGINEERING SERVICE CENTER<br>PORT HUENEME, CALIFORNIA 93043<br>DUEL FUEL 1500 KW<br>CONVERSION OF DIESEL POWER PLANTS<br>SCHEMATIC DIAGRAM<br>ENGINE CONTROL CIRCUITS<br>SIZE CORE IDENT NO<br><b>F 80091</b><br>CONVENT CONTR NO<br>SCALE NONE<br>SPEC<br>SHEET 1 OF |          |             |          |

3



REF.DWG.  
6278575

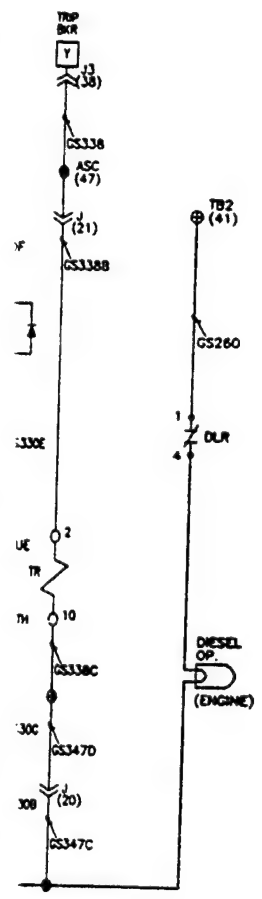




IF IN DOUBT, ASK - DO NOT SCALE

| REVISIONS |             |      |          |
|-----------|-------------|------|----------|
| ITEM      | DESCRIPTION | DATE | APPROVAL |

5 17 18 19 20



LEGEND

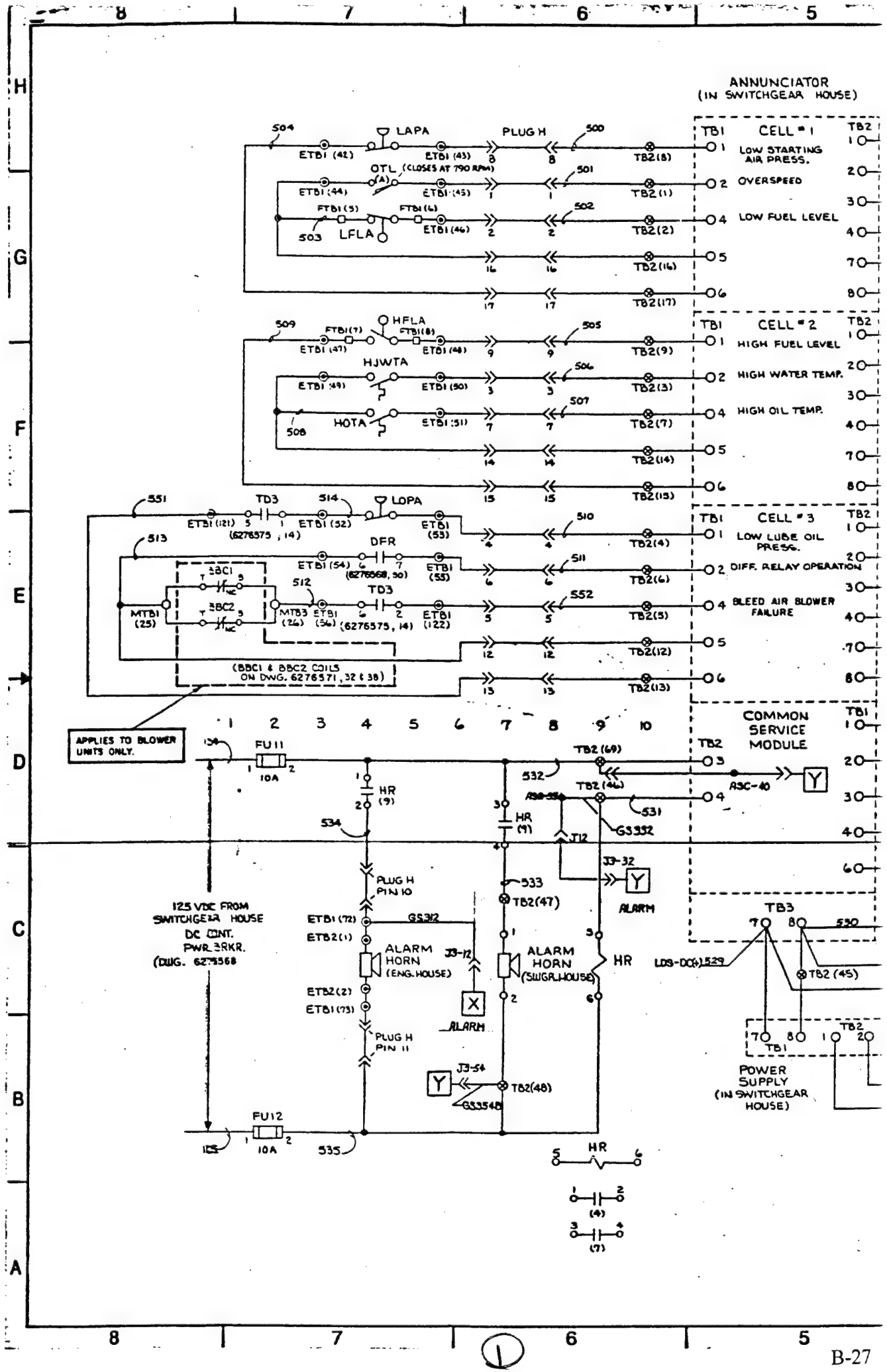
- DCR - DIESEL CONTROL RAM
- DLR - DIESEL LIGHT RELAY
- ETH - ETHER INJECTION RELAY
- GR - GAS RUN
- LD - LEAK DETECTION
- R2 - RACK POSITION TWO
- R3 - RACK POSITION THREE
- TR - TRIP MAIN BREAKER RELAY

- X - ECU INPUT
- Y - ECU OUTPUT 130V DC

|                                                                                                                |  |                                                                                                                                                                             |          |                                                                                              |          |
|----------------------------------------------------------------------------------------------------------------|--|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------|----------------------------------------------------------------------------------------------|----------|
| QUANTITY FOR EACH ASSEMBLY                                                                                     |  | ITEM NO.                                                                                                                                                                    | PART NO. | DESCRIPTION                                                                                  | MATERIAL |
| PARTS LIST                                                                                                     |  |                                                                                                                                                                             |          |                                                                                              |          |
| UNLESS OTHERWISE SPECIFIED<br>DIMENSIONS ARE IN FEET AND/OR INCHES                                             |  | DEPARTMENT OF THE NAVY<br>NAVAL FACILITIES ENGINEERING SERVICE CENTER<br>PORT HUENEME, CALIFORNIA 93043                                                                     |          |                                                                                              |          |
| TOLERANCES:<br>.X DECIMALS<br>.XX DECIMALS<br>.XXX DECIMALS<br>FRACTIONS $\pm 1/16"$<br>ANGLES $\pm 0.5^\circ$ |  | DUEL FUEL 1500 KW<br>CONVERSION OF DIESEL POWER PLANTS<br>SCHEMATIC DIAGRAM<br>ENGINE CONTROL CIRCUITS                                                                      |          |                                                                                              |          |
| PART DASH NO.<br>NEXT ASSY.                                                                                    |  | PROJ. NO.<br>DES. NO. 7888- DF<br>DES. BY FOR F. DELALANERA<br>CHK. BY<br>BRANCH HEAD E. MACH.<br>DES. DES.<br>SATISFACTORY TO<br>MIKE CHILBERS<br>NORMAN HELGESON DEC 1978 |          | SHEET CODE ECUW NO<br>F 80091<br>NAUTIC DRAWING NO<br>CONVENT CONNO NO<br>SCALE NONE<br>SPEC |          |
| APPROVED<br>COMMANDING OFFICER<br>APPROVED<br>FOR COMMANDER, NAUTIC                                            |  | DATE<br>DATE<br>SHEET 1 OF                                                                                                                                                  |          |                                                                                              |          |

IF IN DOUBT, ASK - DO NOT SCALE

3

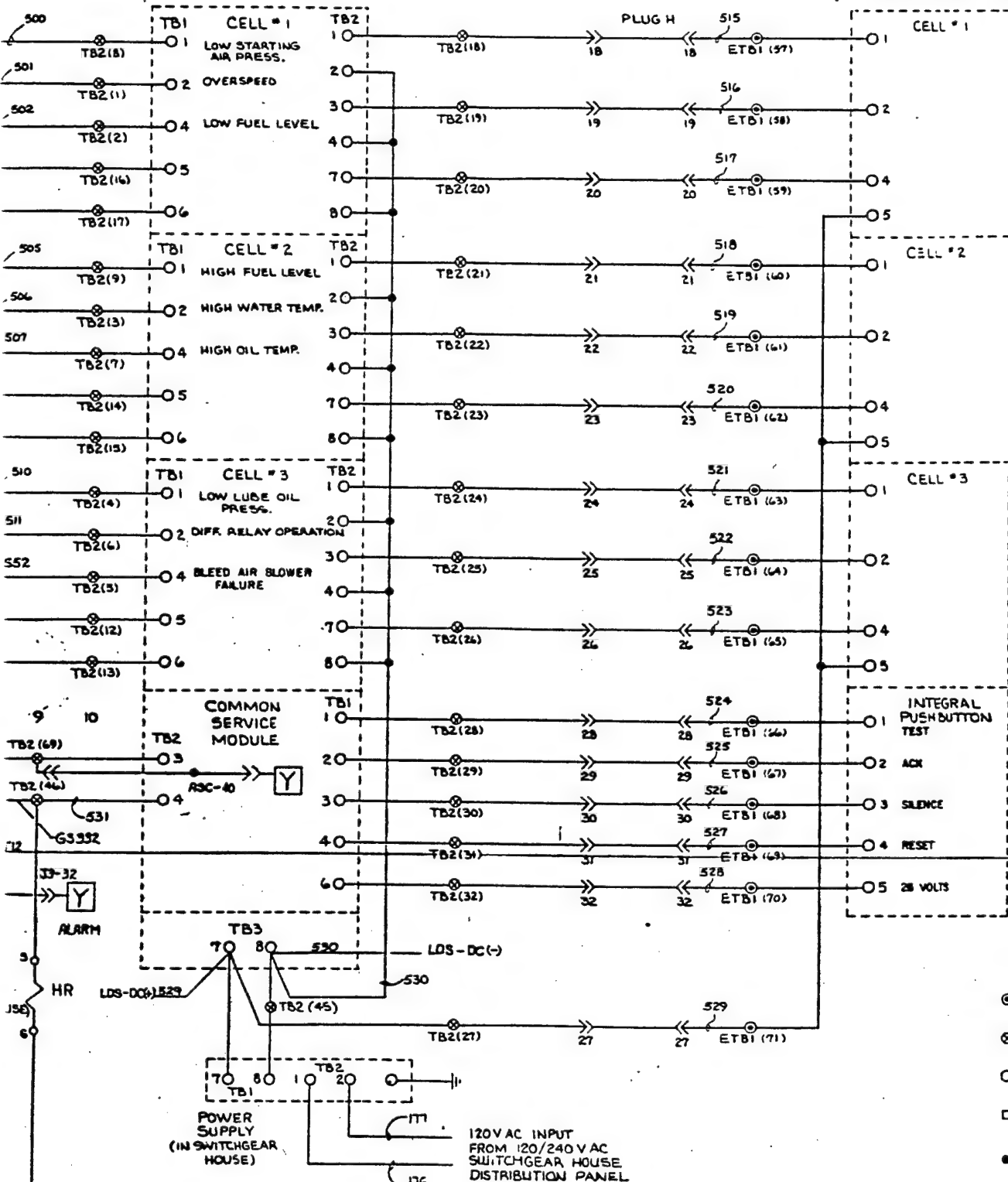


ANNUNCIATOR  
(IN SWITCHGEAR HOUSE)

| CELL # 1              |     |
|-----------------------|-----|
| TB1                   | TB2 |
| 1                     | 10  |
| 2                     | 20  |
| 3                     | 30  |
| 4                     | 40  |
| 5                     | 70  |
| 6                     | 80  |
| CELL # 2              |     |
| TB1                   | TB2 |
| 1                     | 10  |
| 2                     | 20  |
| 3                     | 30  |
| 4                     | 40  |
| 5                     | 70  |
| 6                     | 80  |
| CELL # 3              |     |
| TB1                   | TB2 |
| 1                     | 10  |
| 2                     | 20  |
| 3                     | 30  |
| 4                     | 40  |
| 5                     | 70  |
| 6                     | 80  |
| COMMON SERVICE MODULE |     |
| TB1                   | TB2 |
| 1                     | 10  |
| 2                     | 20  |
| 3                     | 30  |
| 4                     | 40  |
| 5                     | 70  |
| 6                     | 80  |

# ANNUNCIATOR (IN SWITCHGEAR HOUSE)

# ANNUNCIATOR LIGHT BOX (IN ENGINE CONTROL PANEL)



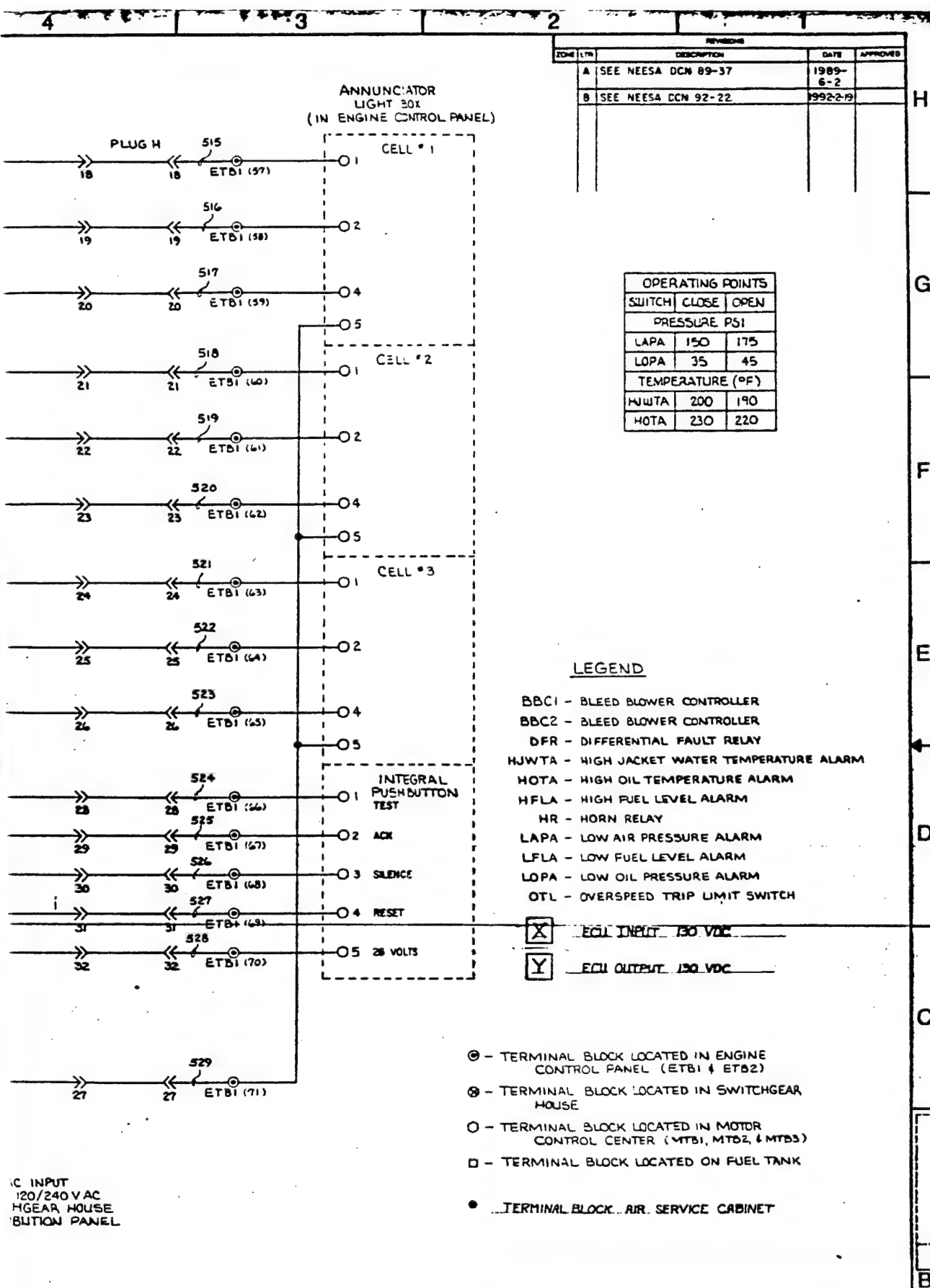
## LEGEND

BBC1 - BLEED BLOW  
BBC2 - BLEED BLOW  
DFR - DIFFERENTIAL  
HJWTA - HIGH JACKET  
HOTA - HIGH OIL TEMP  
HFLA - HIGH FUEL LEVEL  
HR - HORN RELAY  
LAPA - LOW AIR PRESSURE  
LFLA - LOW FUEL LEVEL  
LOPA - LOW OIL PRESSURE  
OTL - OVERSPEED

☒ ECU INPUT  
☐ ECU OUTPUT

⊙ - TERMINAL BLOCK LOCAL CONTROL PANEL  
⊙ - TERMINAL BLOCK LOCAL HOUSE  
○ - TERMINAL BLOCK LOCAL CONTROL CENTER  
□ - TERMINAL BLOCK LOCAL  
• - TERMINAL BLOCK AIR

|                                                        |      |
|--------------------------------------------------------|------|
| 789-DF                                                 |      |
| DESIGNED BY                                            | DATE |
| APPROVED BY                                            | DATE |
| REVIEWED BY                                            | DATE |
| CHIEF ENGINEER                                         | DATE |
| DUEL FUEL 1500 KW<br>CONVERSION OF DIESEL POWER PLANTS |      |
| SUBMITTED TO                                           |      |
| APPROVED BY                                            |      |
| DATE                                                   |      |
| SUBMITTED TO                                           |      |
| APPROVED BY                                            |      |
| DATE                                                   |      |

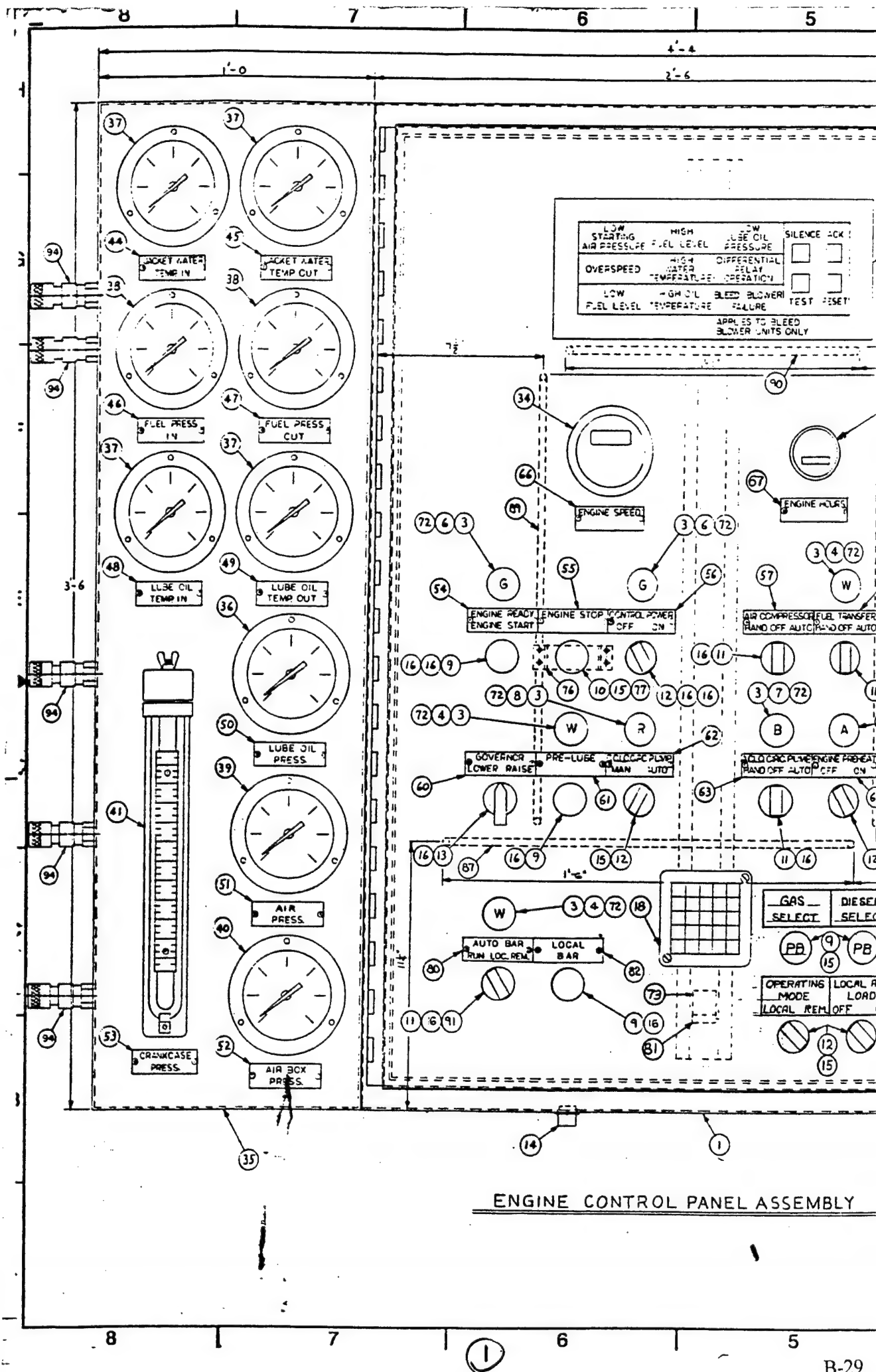


| REVISIONS |           |                     |          |
|-----------|-----------|---------------------|----------|
| ZONE      | DATE      | DESCRIPTION         | APPROVED |
| A         | 1989-6-2  | SEE NEESA DCN 89-37 |          |
| B         | 1992-2-19 | SEE NEESA DCN 92-22 |          |

|                                   |  |                                                                                                            |  |
|-----------------------------------|--|------------------------------------------------------------------------------------------------------------|--|
| NEESA DRAWING NO<br><b>789-DF</b> |  | DEPARTMENT OF THE NAVY<br>NAVAL ENERGY AND ENVIRONMENTAL SUPPORT ACTIVITY<br>PUEBLO, CALIFORNIA 92043-0000 |  |
| PROPOSED WORK BY CHECKER          |  | OVERHAUL 1500 KW DIESEL POWER PLANTS                                                                       |  |
| REVIEWED                          |  | SCHEMATIC DIAGRAM ANNUNCIATOR                                                                              |  |
| DESIGNED BY                       |  | CASE NO<br><b>F 80091</b>                                                                                  |  |
| SEPT HEAD                         |  | NAVAL DRAWING NO<br><b>6276576</b>                                                                         |  |
| DATE                              |  | CROSS REF N47408-89-C-2011                                                                                 |  |
| APPROVED                          |  | SCALE NONE                                                                                                 |  |
| DRAWN BY                          |  | SHEET 30 OF                                                                                                |  |

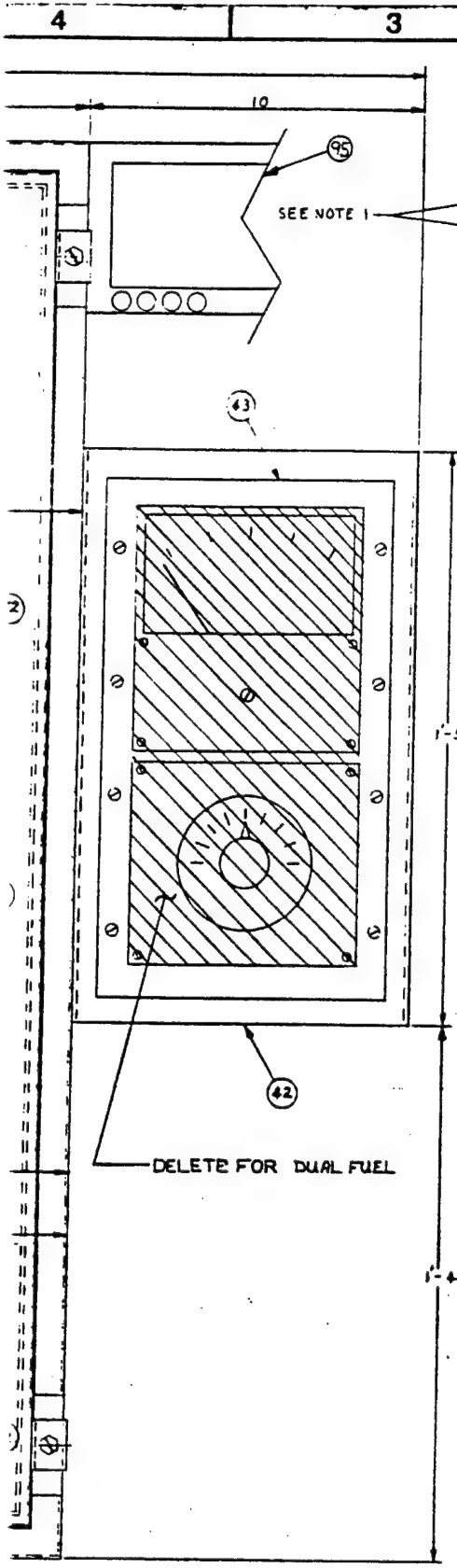
|                                                     |      |
|-----------------------------------------------------|------|
| DUEL FUEL 1500 KW CONVERSION OF DIESEL POWER PLANTS |      |
| SATISFACTORY TO                                     | DATE |
| WILLIE C. GILBERT                                   | 1994 |
| NORMAN HELGESON                                     | 1994 |
| REWORKED BY                                         | DATE |
| WILLIE C. GILBERT                                   | 1994 |
| DESIGNED BY                                         | DATE |
| WILLIE C. GILBERT                                   | 1994 |





ENGINE CONTROL PANEL ASSEMBLY





| 4  |              |                        |                                                                                         | 3 |  |  |  | 2 |  |  |  | 1 |  |  |  |
|----|--------------|------------------------|-----------------------------------------------------------------------------------------|---|--|--|--|---|--|--|--|---|--|--|--|
| 1  |              |                        |                                                                                         | 1 |  |  |  | 1 |  |  |  | 1 |  |  |  |
| 5  | SS-004-BH-00 | GAUGE                  | TEST "AP                                                                                |   |  |  |  |   |  |  |  |   |  |  |  |
| 1  | 5605 10250T3 | CONTACT BLOCK          | CH (2-NC)                                                                               |   |  |  |  |   |  |  |  |   |  |  |  |
| 1  | 13137        | MS-2-44                | MARKER STRAP                                                                            |   |  |  |  |   |  |  |  |   |  |  |  |
| 1  |              |                        | NAMEPLATE (LOCAL BAR)                                                                   |   |  |  |  |   |  |  |  |   |  |  |  |
| 1  |              |                        | NAMEPLATE (AUTO BAR/RUN LOC. REM.)                                                      |   |  |  |  |   |  |  |  |   |  |  |  |
| 1  |              |                        | CONTACT PLATE (OPERATOR) (FOR ITEM 10)                                                  |   |  |  |  |   |  |  |  |   |  |  |  |
| 1  | 13137        | 2-141                  | MTG. BRACKET (CONTACT BLOCK) (FOR ITEM 15)                                              |   |  |  |  |   |  |  |  |   |  |  |  |
| 1  | 13137        | 2-141                  | TERMINAL SCARDI TRW (FOR ITEM 18) (ETB-2)                                               |   |  |  |  |   |  |  |  |   |  |  |  |
| 10 | 13138        | 65C-120V               | LIGHT BULB SYL (FOR ITEM 3)                                                             |   |  |  |  |   |  |  |  |   |  |  |  |
| 1  |              |                        | NAMEPLATE (ENGINE HOURS)                                                                |   |  |  |  |   |  |  |  |   |  |  |  |
| 1  |              |                        | (ENGINE SPEED)                                                                          |   |  |  |  |   |  |  |  |   |  |  |  |
| 1  |              |                        | (EXHAUST FAN/OFF ON)                                                                    |   |  |  |  |   |  |  |  |   |  |  |  |
| 1  |              |                        | (ENGINE PREHEAT/OFF ON)                                                                 |   |  |  |  |   |  |  |  |   |  |  |  |
| 1  |              |                        | (AC L.O. CIRC. PUMP/HAND OFF AUTO)                                                      |   |  |  |  |   |  |  |  |   |  |  |  |
| 1  |              |                        | (DC L.O. CIRC. PUMP/MAN. AUTO)                                                          |   |  |  |  |   |  |  |  |   |  |  |  |
| 1  |              |                        | (PRE-LUBE)                                                                              |   |  |  |  |   |  |  |  |   |  |  |  |
| 1  |              |                        | (GOVERNOR/LOWER RAISE)                                                                  |   |  |  |  |   |  |  |  |   |  |  |  |
| 1  |              |                        | (FUEL TRANSFER (MODE)/PUMP GRAVITY)                                                     |   |  |  |  |   |  |  |  |   |  |  |  |
| 1  |              |                        | (FUEL TRANSFER (SEL)/HAND OFF AUTO)                                                     |   |  |  |  |   |  |  |  |   |  |  |  |
| 1  |              |                        | (AIR COMPRESSOR/HAND OFF AUTO)                                                          |   |  |  |  |   |  |  |  |   |  |  |  |
| 1  |              |                        | (CONTROL POWER/OFF ON)                                                                  |   |  |  |  |   |  |  |  |   |  |  |  |
| 1  |              |                        | (ENGINE STOP)                                                                           |   |  |  |  |   |  |  |  |   |  |  |  |
| 1  |              |                        | (ENGINE READY/ENGINE START)                                                             |   |  |  |  |   |  |  |  |   |  |  |  |
| 1  |              |                        | (CRANKCASE PRESS.)                                                                      |   |  |  |  |   |  |  |  |   |  |  |  |
| 1  |              |                        | (AIR BOX PRESS.)                                                                        |   |  |  |  |   |  |  |  |   |  |  |  |
| 1  |              |                        | (AIR PRESS.)                                                                            |   |  |  |  |   |  |  |  |   |  |  |  |
| 1  |              |                        | (LUBE OIL PRESS.)                                                                       |   |  |  |  |   |  |  |  |   |  |  |  |
| 1  |              |                        | (LUBE OIL TEMP. OUT)                                                                    |   |  |  |  |   |  |  |  |   |  |  |  |
| 1  |              |                        | (LUBE OIL TEMP. IN)                                                                     |   |  |  |  |   |  |  |  |   |  |  |  |
| 1  |              |                        | (FUEL PRESS. OUT)                                                                       |   |  |  |  |   |  |  |  |   |  |  |  |
| 1  |              |                        | (FUEL PRESS. IN)                                                                        |   |  |  |  |   |  |  |  |   |  |  |  |
| 1  |              |                        | (JACKET WATER TEMP OUT)                                                                 |   |  |  |  |   |  |  |  |   |  |  |  |
| 1  |              |                        | (JACKET WATER TEMP IN)                                                                  |   |  |  |  |   |  |  |  |   |  |  |  |
| 1  | 01518        | 603-302-074            | NAMEPLATE (ALNOR (ENG. EXHAUST MODEL FND)                                               |   |  |  |  |   |  |  |  |   |  |  |  |
| 1  |              |                        | PANEL (EXHAUST PYROMETER)                                                               |   |  |  |  |   |  |  |  |   |  |  |  |
| 1  | 13139        | 10AA25WM               | MANOMETER (MERIAM CRANKCASE PRESS.)                                                     |   |  |  |  |   |  |  |  |   |  |  |  |
| 1  | 178763       | 893 0-30               | GAUGE (TRERICE (AIR BOX PRESS. 0-30)                                                    |   |  |  |  |   |  |  |  |   |  |  |  |
| 1  | 178763       | 893 0-300              | GAUGE (TRERICE (START AIR PRESS. 0-300)                                                 |   |  |  |  |   |  |  |  |   |  |  |  |
| 1  | 178763       | 893 0-100              | GAUGE (TRERICE (FUEL PRESS. IN & OUT 0-100)                                             |   |  |  |  |   |  |  |  |   |  |  |  |
| 1  | 178763       | V80040                 | GAUGE (TRERICE (LUBE OIL & WATER TEMP IN & OUT 30-240)                                  |   |  |  |  |   |  |  |  |   |  |  |  |
| 1  | 178763       | 893 0-160              | GAUGE (TRERICE (LUBE OIL PRESS. 0-160)                                                  |   |  |  |  |   |  |  |  |   |  |  |  |
| 1  |              |                        | GAUGE PANEL                                                                             |   |  |  |  |   |  |  |  |   |  |  |  |
| 1  | 154571       | SPD-108                | TACHOMETER (DYNALCO (ENG. SPEED 0-1000 RPM)                                             |   |  |  |  |   |  |  |  |   |  |  |  |
| 1  | 12K221       | 450-125V               | ALARM HORN (FEDERAL)                                                                    |   |  |  |  |   |  |  |  |   |  |  |  |
| 1  | 10583        | 12729-12               | METER (CURTIS (RUNNING TIME 0-99,999)                                                   |   |  |  |  |   |  |  |  |   |  |  |  |
| 1  | 15605        | 10250T2                | CONTACT BLOCK (CH (2-NO)                                                                |   |  |  |  |   |  |  |  |   |  |  |  |
| 1  | 15605        | 10250T1                | CONTACT BLOCK (CH (1-NO & 1-NC)                                                         |   |  |  |  |   |  |  |  |   |  |  |  |
| 1  | 12915        | 8458522                | RECEPTACLE (EMD (AUTO BAR)                                                              |   |  |  |  |   |  |  |  |   |  |  |  |
| 1  | 15605        | 10250T3C43             | SWITCH (CH (GOVERNOR CONTROL)                                                           |   |  |  |  |   |  |  |  |   |  |  |  |
| 1  | 15605        | 10250T1311             | SWITCH (CH (FUEL TRANS. MODE, ENG. PRE-HEAT, CONTR. PWR., DC L.O. CIRC. PUMP, EXH. FAN) |   |  |  |  |   |  |  |  |   |  |  |  |
| 1  | 15605        | 10250T1323             | SWITCH (CH (AC MODE, FUEL TRANS. SEL, AC L.O. C.P., AUTO BAR)                           |   |  |  |  |   |  |  |  |   |  |  |  |
| 1  | 15605        | 10935H5                | OPERATOR (CH (RED) (ENG. STOP)                                                          |   |  |  |  |   |  |  |  |   |  |  |  |
| 1  | 15605        | 10250T101              | PUSH BUTTON (CH (BLACK) (ENG. START) (LOCAL BAR) (PRELUBE)                              |   |  |  |  |   |  |  |  |   |  |  |  |
| 1  | 15605        | 10250TC1N              | LENS CAP (CH (RED) (DC LUBE PUMP)                                                       |   |  |  |  |   |  |  |  |   |  |  |  |
| 1  | 15605        | 10250TC4N              | LENS CAP (CH (BLUE) (AC LUBE PUMP)                                                      |   |  |  |  |   |  |  |  |   |  |  |  |
| 1  | 15605        | 10250TC2N              | LENS CAP (CH (GREEN) (POWER ON, ENG. READY)                                             |   |  |  |  |   |  |  |  |   |  |  |  |
| 1  | 15605        | 10250TC19N             | LENS CAP (CH (AMBER) (ENG. PRE-HEAT)                                                    |   |  |  |  |   |  |  |  |   |  |  |  |
| 1  | 15605        | 10250TC6N              | LENS CAP (CH (WHITE) (PRE-LUBE, FUEL TRANS., AUTO BAR)                                  |   |  |  |  |   |  |  |  |   |  |  |  |
| 1  | 15605        | 10250T201N1            | SOCKET (CH (INDICATING LIGHTS)                                                          |   |  |  |  |   |  |  |  |   |  |  |  |
| 1  | 32582        | AN-5131-1HX4W-3-9W-STH | BOX (ROCH (ANNUNCIATOR LIGHTS)                                                          |   |  |  |  |   |  |  |  |   |  |  |  |
| 1  | 00843        | A-423098               | LPI CABINET ECP (HOFFMAN (42 X 30 X 8)                                                  |   |  |  |  |   |  |  |  |   |  |  |  |

|                       |  |          |  |          |  |           |  |           |  |         |  |         |  |             |  |             |  |
|-----------------------|--|----------|--|----------|--|-----------|--|-----------|--|---------|--|---------|--|-------------|--|-------------|--|
| A SEE NEESA DCN 92-12 |  | 1992-1-8 |  | DATE     |  | APPROVED  |  | SIGNATURE |  | DATE    |  | CASE NO |  | PART NO     |  | SHEET 31 OF |  |
| DESCRIPTION           |  | DATE     |  | APPROVED |  | SIGNATURE |  | DATE      |  | CASE NO |  | PART NO |  | SHEET 31 OF |  |             |  |
| REVISIONS             |  | DATE     |  | APPROVED |  | SIGNATURE |  | DATE      |  | CASE NO |  | PART NO |  | SHEET 31 OF |  |             |  |

790-DF

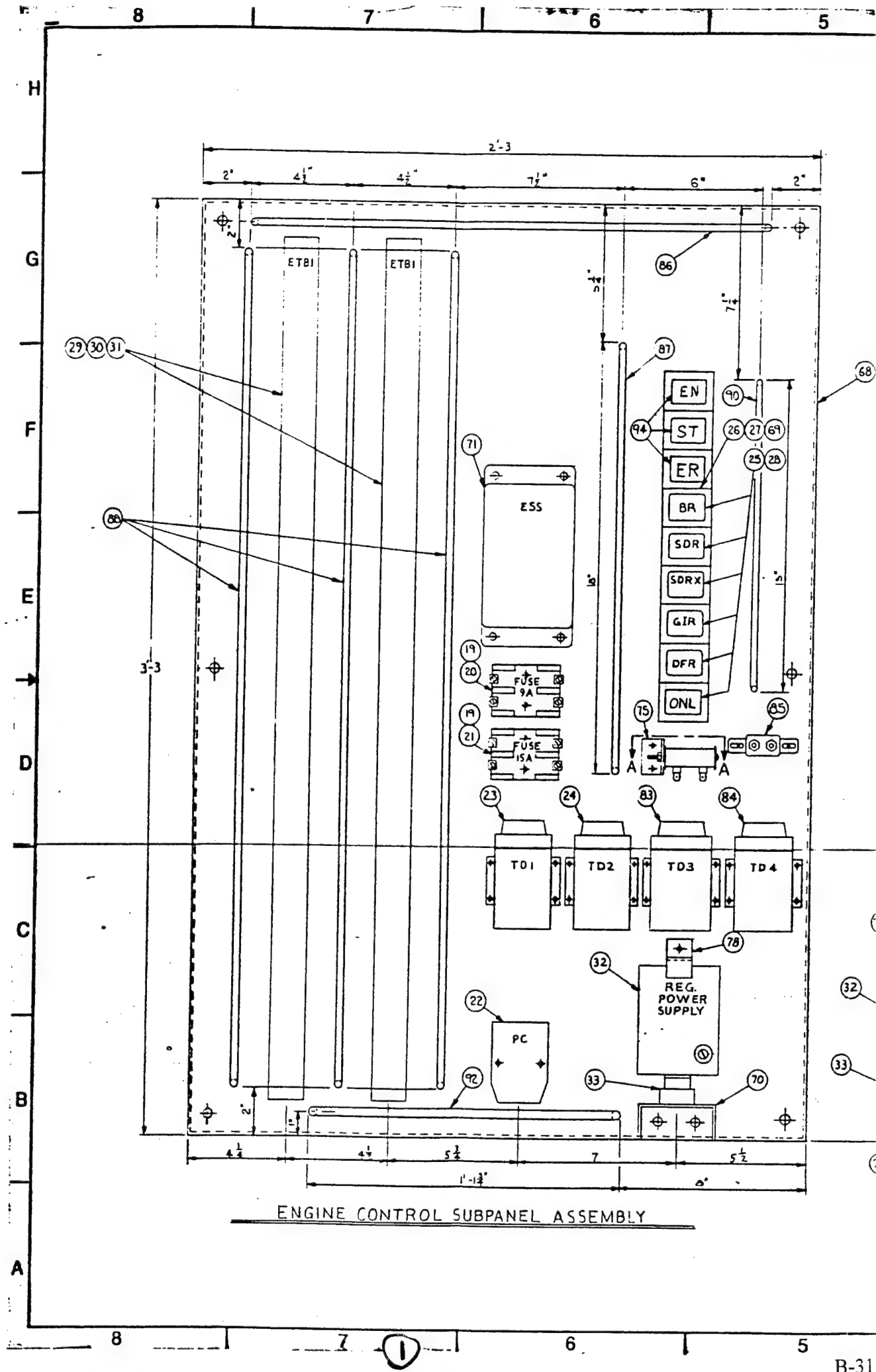
OVERHAUL 1500 KW DIESEL POWER PLANTS

ENGINE CONTROL AND SUBPANEL ASSEMBLY

6276577

F 80091

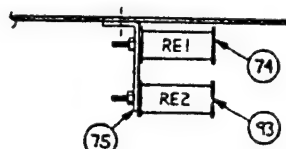
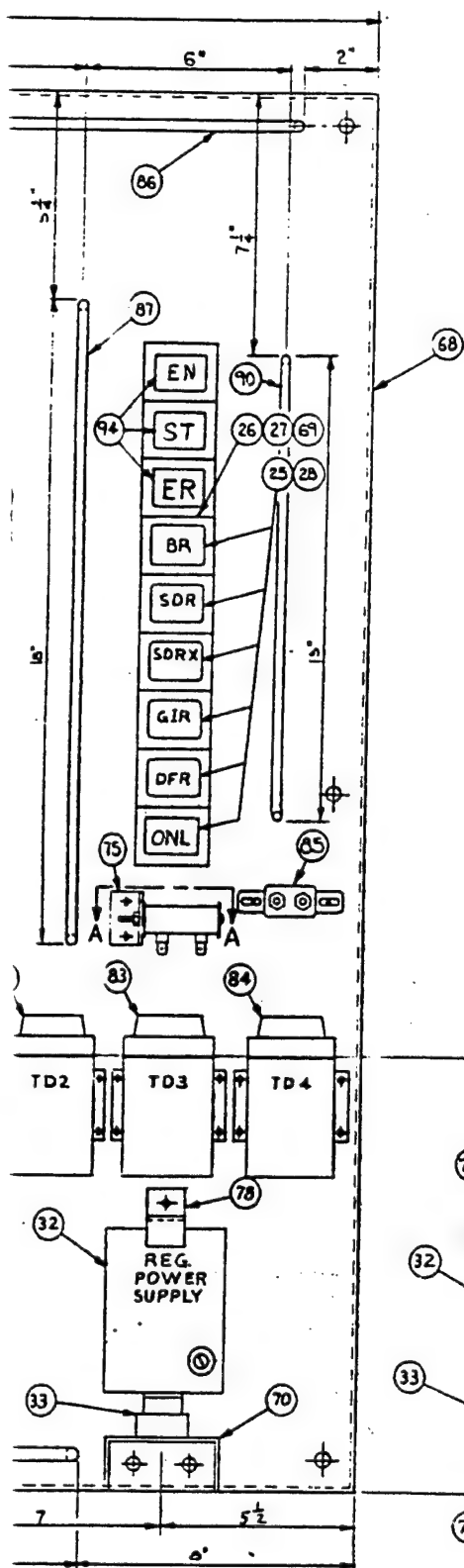
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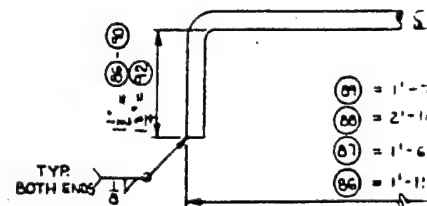
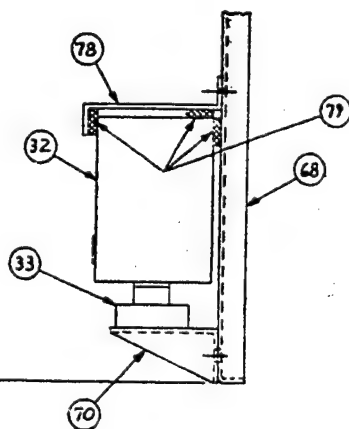
| ZONE | LTR   |
|------|-------|
| A    | SEE D |

## LEGEND

BR — BARRING RELAY  
 DFR — DIFFERENTIAL FAULT RELAY  
 ESS — ELECTRONIC SPEED SWITCH  
 ETB-1 — ENGINE CONTROL PANEL TERMINAL BOARD  
 GIR — GOVERNOR IDLE RELAY  
 PC — PUMP CONTROLLER (D.C.)  
 CR1 — RECTIFIER  
 RE1 — RESISTOR  
 SDR — SHUTDOWN RELAY  
 SDRX — SHUTDOWN RELAY AUXILIARY  
 TD1 — TIME DELAY RELAY  
 TD2 — TIME DELAY RELAY  
 TD3 — TIME DELAY RELAY  
 TD4 — TIME DELAY RELAY  
 RE2 — RESISTOR



SECTION A-A



TIE BAR DET.

U.T.S.

| QTY | FROM NO. | PART OR IDENTIFYING NO. | NOMENCLATURE OR DESCRIPTION | PARTS LIT. |
|-----|----------|-------------------------|-----------------------------|------------|
| 3   |          | KRD14DG                 | RELAY                       | S          |
| 1   |          | 10015-R150              | RESISTOR RE2                | S          |
| 1   |          |                         | TIE BAR                     | 3/4" F     |
| 2   |          |                         | TIE BAR                     | 1/2" F     |
| 2   |          |                         | TIE BAR                     | 1/4" R     |
| 3   |          |                         | TIE BAR                     | 1/4" R     |
| 2   |          |                         | TIE BAR                     | 1/4" R     |
| 1   |          |                         | TIE BAR                     | 1/4" R     |
| 1   | 30187    | 3405-3                  | RECTIFIER-CR1               | SAL        |
| 1   | 70382    | 7022PFI2M               | RELAY-TD4                   | AGA        |
| 1   | 70382    | 7012PDI2M               | RELAY-TD3                   | AGA        |
| 1   |          |                         | SPONGE RUBBER               |            |
| 1   |          |                         | CLAMP                       |            |
| 1   |          |                         | MTG. BRACKET                |            |
| 1   | 72915    | 8290343                 | RESISTOR-RE1                | EM         |
| 1   | 78388    | E55B-2AT                | SWITCH-ESS                  | SYN        |
| 1   |          |                         | MTG. BRACKET                |            |
| 2   | 81487    | 8501-NH10               | END CLAMP                   | SQ         |
| 1   | 00843    | A-42 P30                | PANEL                       | HOF        |
| 1   | 81487    | 8501-NR52               | SOCKET                      | SQ         |
| 1   | 14749    | 5J20                    | POWER SUPPLY                | ACOF       |
| 2   | 02261    | 67                      | TRACK                       | BU         |
| 4   | 02261    | 0530                    | END SECTION                 | BU         |
| 12  | 02261    | 0511                    | TERM. BLOCK                 | BU         |
| 5   | 81487    | 8501-NH2                | CLIP                        | SQ         |
| 1   | 81487    | 8501-NH13               | TRACK                       | SQ         |
| 6   | 81487    | 8501-NR42               | SOCKET                      | SQ         |
| 6   | 81487    | 8501-KPD13              | RELAY                       | SQ         |
| 1   | 70382    | 7022PFI2M               | RELAY-TD2                   | AGA        |
| 1   | 70382    | 7022PDI2M               | RELAY-TD1                   | AGA        |
| 1   | 77342    | PRD-11DHO-110           | CONTACTOR-PC                | P          |
| 2   | 71400    | NON-15                  | FUSE                        | BUS        |
| 2   | 71400    | FRN-9                   | FUSE                        | BUS        |
| 2   | 71400    | 180002                  | FUSE BLOCK                  | BUS        |

SEMBLY

DUEL FUEL 1500 KW  
 COMMISSION OF DIESEL POWER PLANTS

SATISFACTORY TO  
 NAME: CHIEF  
 NORMAN HELGSON

DATE: 10/1/58

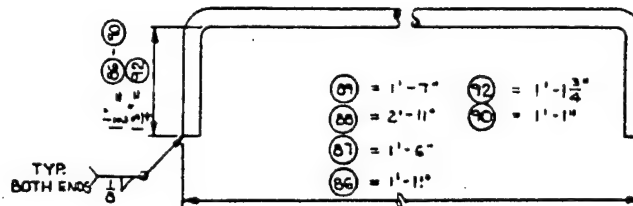
APPROVED  
 NAME: [Signature]  
 CHIEF OFFICE

791-DF

REVIEWED: [Signature]  
 CHECKED: [Signature]  
 DATE: 10/1/58

# LEGEND

BR — BARRING RELAY.  
 DFR — DIFFERENTIAL FAULT RELAY  
 ESS — ELECTRONIC SPEED SWITCH  
 ETB-1 — ENGINE CONTROL PANEL TERMINAL BOARD  
 GIR — GOVERNOR IDLE RELAY  
 PC — PUMP CONTROLLER (D.C.)  
 CR1 — RECTIFIER  
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 SDRX — SHUTDOWN RELAY AUXILIARY  
 TD1 — TIME DELAY RELAY  
 TD2 — TIME DELAY RELAY  
 TD3 — TIME DELAY RELAY  
 TD4 — TIME DELAY RELAY  
 RE2 — RESISTOR

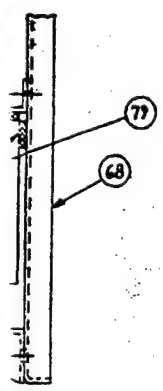
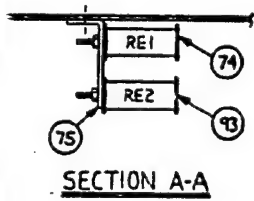


TIE BAR DETAIL

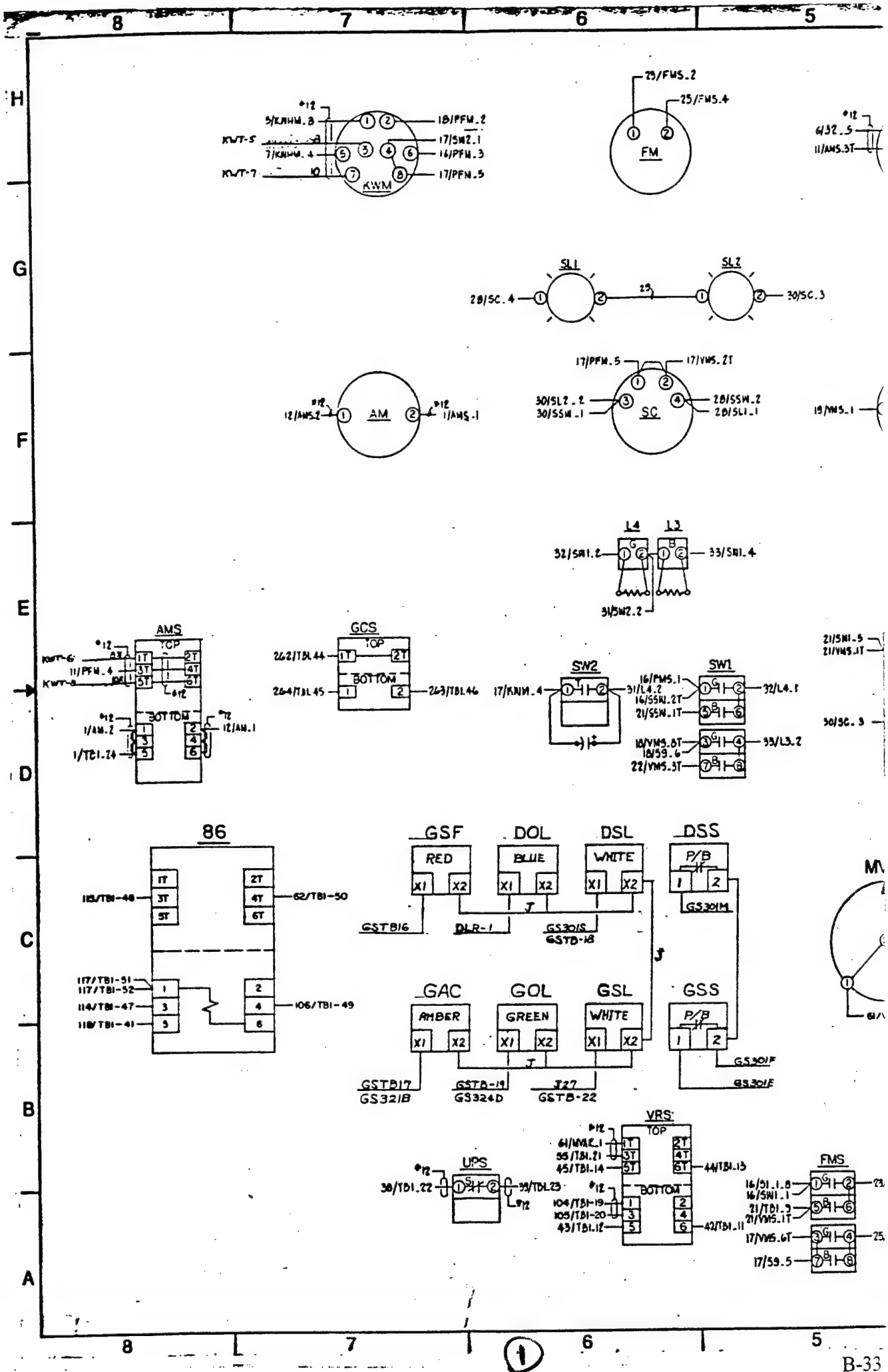
U.T.S.

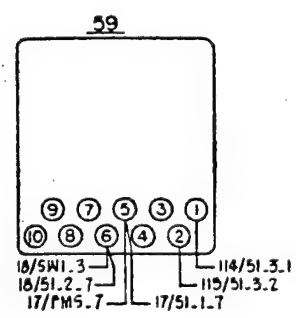
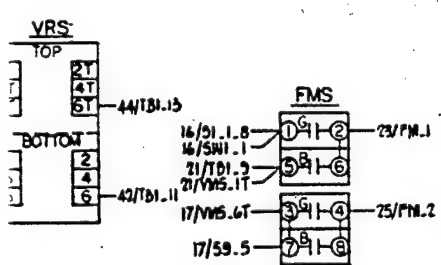
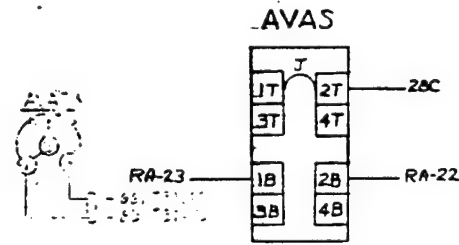
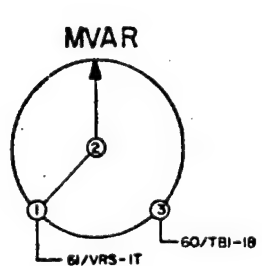
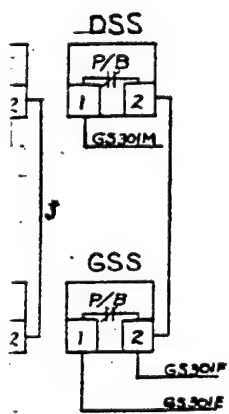
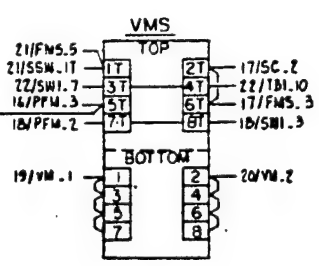
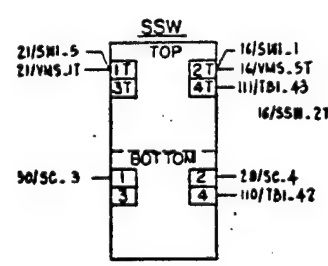
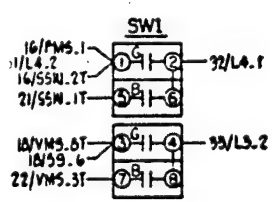
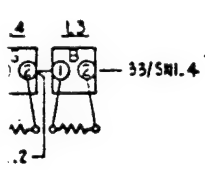
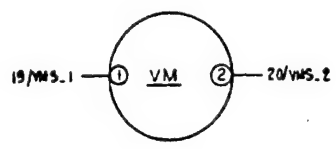
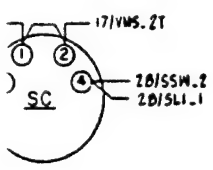
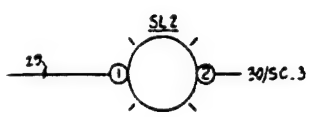
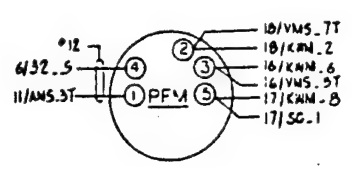
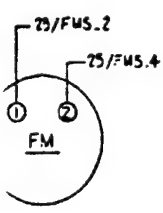
|   |                     |               |                                               |    |
|---|---------------------|---------------|-----------------------------------------------|----|
| 3 | KRD14DG             | RELAY         | SQ.D. (EN, ST, ER)                            | 94 |
| 1 | 10015-R150          | RESISTOR RE2  | (150Ω, 25 WATT)                               | 13 |
| 1 |                     | TIE BAR       | 3/8" ROD X 1'-5 1/4"                          | 92 |
| 2 |                     | TIE BAR       | 1/2" ROD X 1'-4 1/2"                          | 90 |
| 2 |                     | TIE BAR       | 1/2" ROD X 1'-10 1/2"                         | 89 |
| 3 |                     | TIE BAR       | 1/2" ROD X 3'-2 1/2"                          | 86 |
| 2 |                     | TIE BAR       | 1/2" ROD X 1'-9 1/2"                          | 87 |
| 1 |                     | TIE BAR       | 1/2" ROD X 2'-2 1/2"                          | 86 |
| 1 | 30187 3405-3        | RECTIFIER-CR1 | SALEM                                         | 85 |
| 1 | 70382 7022PFI2M     | RELAY-TD4     | AGASTAT (1-10 MIN.) (TDDO)                    | 84 |
| 1 | 70382 7012PDI2M     | RELAY-TD3     | AGASTAT (5-50 SEC.) (TDDU)                    | 83 |
| 1 |                     | SPONGE RUBBER | 3/4 X 5/16 X 3                                | 79 |
| 1 |                     | CLAMP         | (FOR ITEM 32)                                 | 78 |
| 1 |                     | MTG. BRACKET  | (FOR ITEMS 74 & 73)                           | 75 |
| 1 | 72915 8290343       | RESISTOR-RE1  | EMO (6.5K-25 WATT)                            | 74 |
| 1 | 78388 ESSB-2AT      | SWITCH-ESS    | SYN. ST. 20 VDC (ELECTRONIC SPEED)            | 71 |
| 1 |                     | MTG. BRACKET  | (FOR ITEM 33)                                 | 70 |
| 2 | 81487 8501-NH10     | END CLAMP     | SQ-D (FOR ITEM 27)                            | 69 |
| 1 | 00843 A-42 P30      | PANEL         | HOFFMAN (EQUIPMENT MOUNTING)                  | 68 |
| 1 | 81487 8501-NRS2     | SOCKET        | SQ-D (FOR ITEM 32)                            | 33 |
| 1 | 14749 SJ20          | POWER SUPPLY  | ACOPAN (REGULATED POWER SUPPLY)               | 32 |
| 2 | 02261 67            | TRACK         | BUCH (FOR ITEM 29)                            | 31 |
| 4 | 02261 0530          | END SECTION   | BUCH (FOR ITEM 29)                            | 30 |
| 1 | 02261 0511          | TERM. BLOCK   | BUCH (ETB1)                                   | 29 |
| 5 | 81487 8501-NH2      | CLIP          | SQ-D (RELAY RETAINING, FOR ITEM 25)           | 28 |
| 1 | 81487 8501-NH13     | TRACK         | SQ-D (RELAY MTG. FOR ITEM 25)                 | 27 |
| 5 | 81487 8501-NR42     | SOCKET        | SQ-D (RELAY MTG. FOR ITEM 25)                 | 26 |
| 6 | 81487 8501-KPD13    | RELAY         | SQ-D (SDR, SDRX, GIR, DFR, BR) (125 VDC COIL) | 25 |
| 1 | 70382 7022PFI2M     | RELAY-TD2     | AGASTAT (6-60 MIN) (TDDO)                     | 24 |
| 1 | 70382 7022PDI2M     | RELAY-TD1     | AGASTAT (5-50 SEC.) (TDDO)                    | 23 |
| 1 | 77342 PRD-11DHO-110 | CONTACTOR-PC  | P&B (110 VDC COIL)                            | 22 |
| 2 | 71400 NON-15        | FUSE          | BUSS (CONTROL PWR. - 15A)                     | 21 |
| 2 | 71400 FRN-9         | FUSE          | BUSS (DC L.O. CIRC. PUMP-9A)                  | 20 |
| 2 | 71400 180002        | FUSE BLOCK    | BUSS                                          | 19 |

|                                                                                                                             |  |                                                                                                                       |  |                                                                                                                                            |  |
|-----------------------------------------------------------------------------------------------------------------------------|--|-----------------------------------------------------------------------------------------------------------------------|--|--------------------------------------------------------------------------------------------------------------------------------------------|--|
| DUEL FUEL 1500 KW<br>CONVERSION OF DIESEL POWER PLANTS<br>Satisfactory to:<br>NAME: CHILDS<br>NORMAN HELGESON<br>DATE: 1998 |  | 791-DF<br>PREPARED BY: [Signature]<br>REVIEWED BY: [Signature]<br>DESIGNED BY: [Signature]<br>CHECKED BY: [Signature] |  | OVERHAUL 1500 KW<br>DIESEL POWER PLANTS<br>ENGINE CONTROL AND SUBPANEL ASSEMBLY<br>CASE NO: 80091<br>DRAWING NO: 6276578<br>SHEET 32 OF 32 |  |
|-----------------------------------------------------------------------------------------------------------------------------|--|-----------------------------------------------------------------------------------------------------------------------|--|--------------------------------------------------------------------------------------------------------------------------------------------|--|







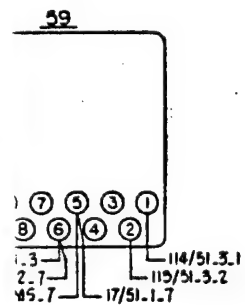
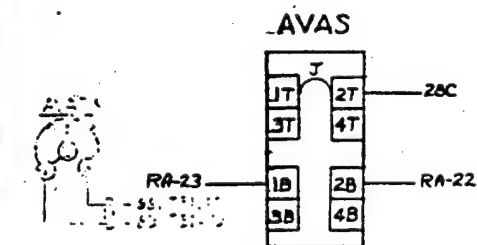
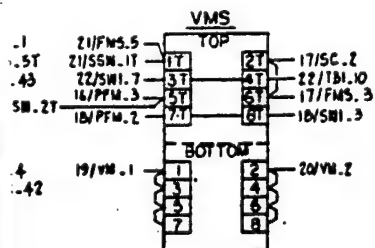


| REV                            | FROM NO | PART OR IDENTIFYING NO | NOMENCLATURE OR DESCRIPTION | DATE |
|--------------------------------|---------|------------------------|-----------------------------|------|
| PARTS LIST                     |         |                        |                             |      |
| 965-DF                         |         |                        |                             |      |
| DEPARTMENT OF THE NAVAL ENERGY |         |                        |                             |      |
| 1992-7-1                       |         |                        |                             |      |
| METERING                       |         |                        |                             |      |
| F 8009                         |         |                        |                             |      |
| SCALE NONE                     |         |                        |                             |      |

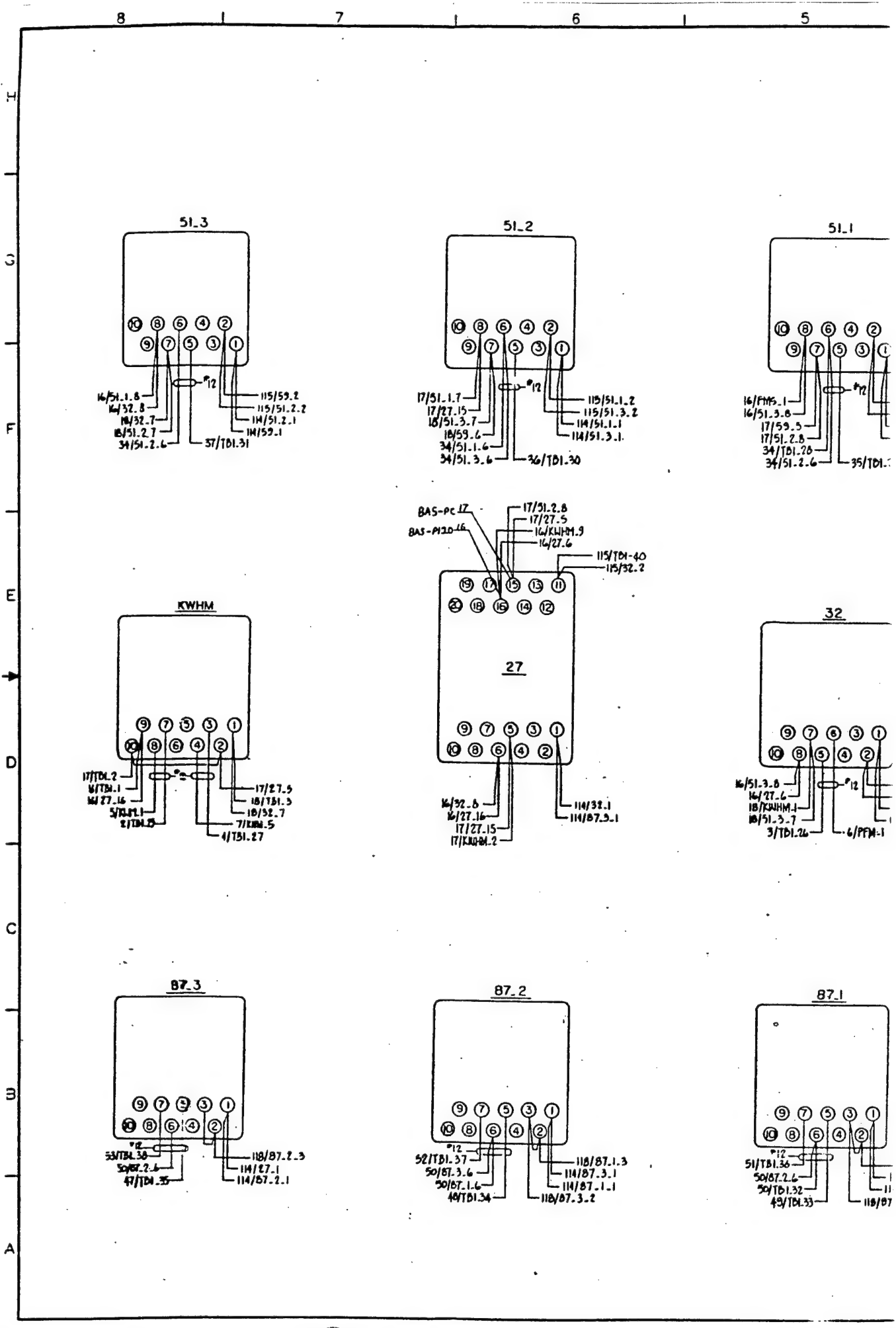


VMS. 7T  
KWM. 2  
KWM. 6  
VMS. 5T  
KWM. 8  
SG. 1

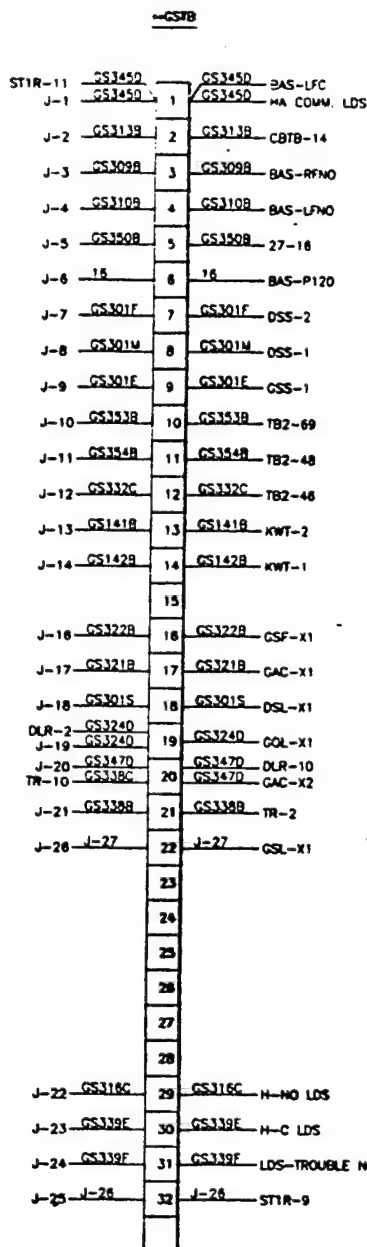
VMS. 2



|                                                            |                         |                                                                                                                               |                        |                                           |
|------------------------------------------------------------|-------------------------|-------------------------------------------------------------------------------------------------------------------------------|------------------------|-------------------------------------------|
| FIG. NO.                                                   | PART OR IDENTIFYING NO. | NOMENCLATURE OR DESCRIPTION                                                                                                   | MATERIAL SPECIFICATION | ITEM NO.                                  |
| PARTS LIST                                                 |                         |                                                                                                                               |                        |                                           |
| 965-DF                                                     |                         | DEPARTMENT OF THE NAVY<br>NAVAL ENERGY AND ENVIRONMENTAL SUPPORT ACTIVITY<br>100 LYONS ST. PORT HUNTER, CALIFORNIA 94622-4240 |                        |                                           |
| DUEL FUEL 1500 KW<br>CONVERSION OF DIESEL POWER PLANTS     |                         | OVERHAUL 1500 KW<br>DIESEL POWER PLANTS<br>METERING CUBICLE DOOR WIRING DIAGRAM                                               |                        |                                           |
| SATISFACTORY TO<br>WIRE CHIEFS<br>NORMAN HELGASON DEC 1998 |                         | DATE                                                                                                                          | SCALE                  | CASE NO.                                  |
|                                                            |                         |                                                                                                                               | NONE                   | F 80091                                   |
|                                                            |                         |                                                                                                                               |                        | NAVJAC<br>DRAWING NO.<br>N47408-89-C-2011 |
|                                                            |                         |                                                                                                                               |                        | SHEET 86 OF                               |

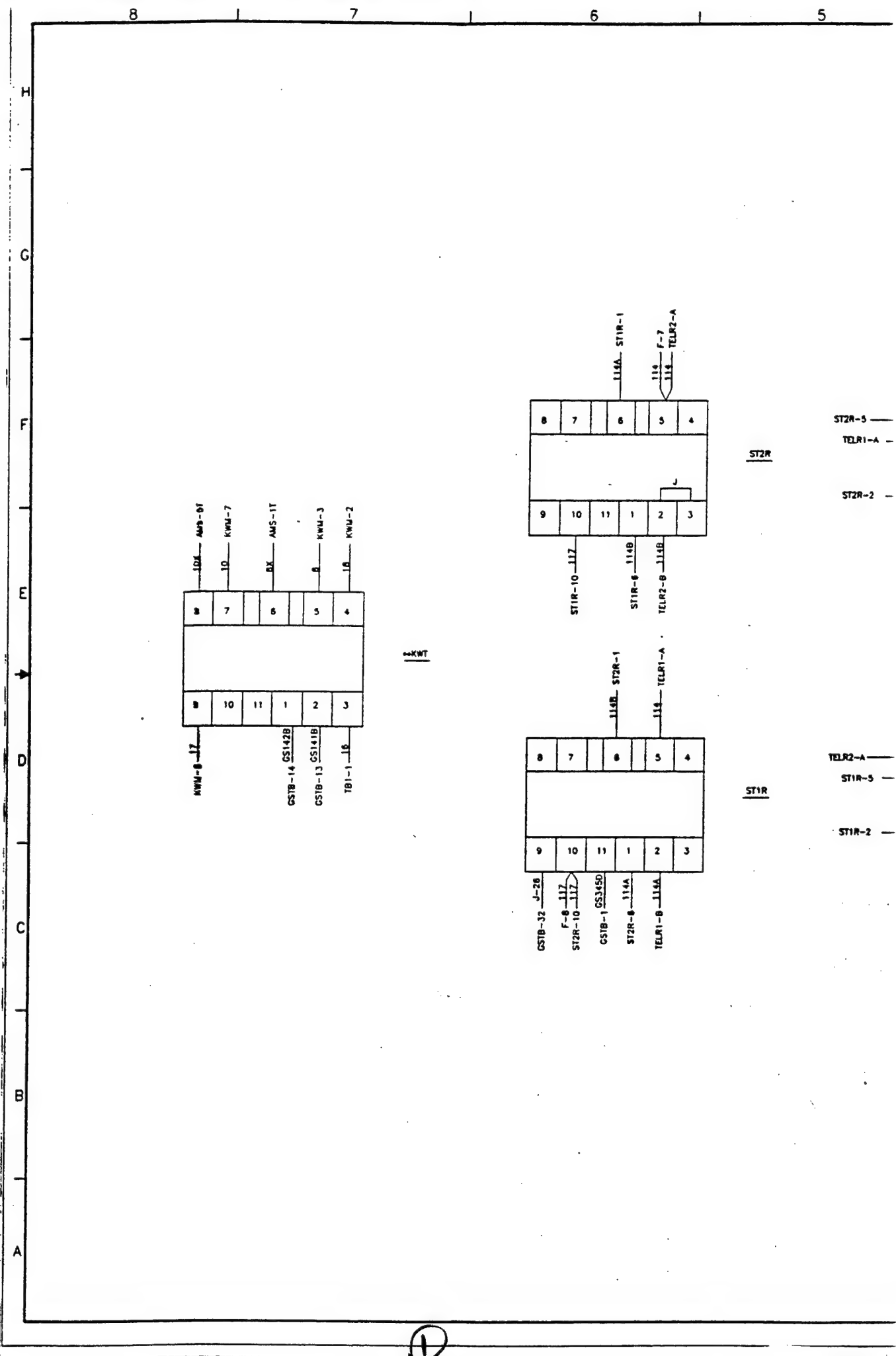


IF IN DOUBT, ASK - DO NOT SCALE

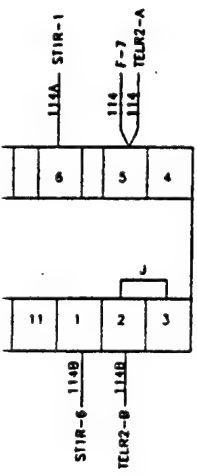


• LOCATED ON LEFT SIDE WALL INTERIOR

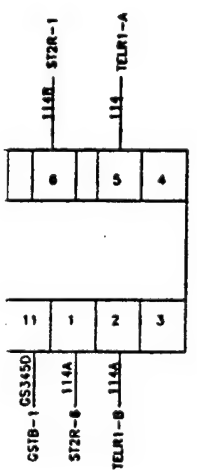
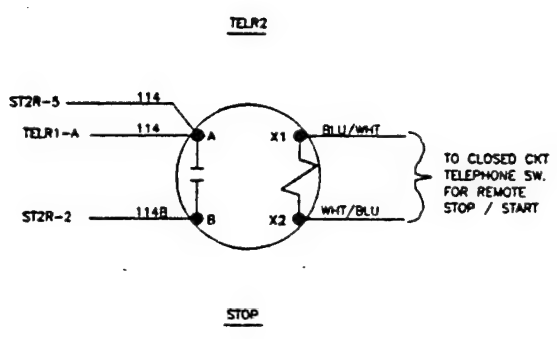
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|                                                                                                                                                                                             |  | ITEM NO.                                                                                                                                                                                          | PART NO. | DESCRIPTION                                                                                                                                                                                                                                               | MATERIAL       |
| QUANTITY FOR EACH ASSEMBLY                                                                                                                                                                  |  | PARTS LIST                                                                                                                                                                                        |          |                                                                                                                                                                                                                                                           |                |
| UNLESS OTHERWISE SPECIFIED<br>DIMENSIONS ARE IN FEET AND/OR INCHES<br><br>TOLERANCES:<br>IN DECIMALS<br>JOINT DECIMALS<br>JOINT DECIMALS<br>FRACTIONS $\pm 1/16"$<br>ANGLES $\pm 0.5^\circ$ |  | PROJ. NO.<br>DWG. NO. <b>966- DF</b><br>DES. BY <b>DR J. DELLABONA</b><br>CHG. XX<br>BRANCH HEAD ID. MARK<br>DIV. OR<br>AUTHORITY TO <b>WIFE CHILDREN</b><br><b>STERNMAN HILGESON - DOW CORP.</b> |          | DEPARTMENT OF THE NAVY<br>NAVAL FACILITIES ENGINEERING COMMAND<br>NAVAL FACILITIES ENGINEERING SERVICE CENTER<br>PORT HUENEME, CALIFORNIA 93043<br><br>DUEL FUEL 1500 KW<br>CONVERSION OF DIESEL POWER PLANTS<br><br>METERING CUBICLE DOOR WIRING DIAGRAM |                |
| PART DATA NO.                                                                                                                                                                               |  | APPROVED                                                                                                                                                                                          | DATE     | SIZE                                                                                                                                                                                                                                                      | CODE IDENT NO. |
| NOT ASSY.                                                                                                                                                                                   |  | COMMANDING OFFICER                                                                                                                                                                                |          | F <b>80091</b>                                                                                                                                                                                                                                            |                |
|                                                                                                                                                                                             |  | APPROVED                                                                                                                                                                                          |          | DATE                                                                                                                                                                                                                                                      |                |
|                                                                                                                                                                                             |  | FOR COMMANDER, NAVFAC                                                                                                                                                                             |          | CONST. CONTR. NO.                                                                                                                                                                                                                                         |                |
|                                                                                                                                                                                             |  |                                                                                                                                                                                                   |          | SCALE NONE                                                                                                                                                                                                                                                |                |
|                                                                                                                                                                                             |  |                                                                                                                                                                                                   |          | SPEC                                                                                                                                                                                                                                                      |                |
|                                                                                                                                                                                             |  |                                                                                                                                                                                                   |          | SHEET 1 OF                                                                                                                                                                                                                                                |                |



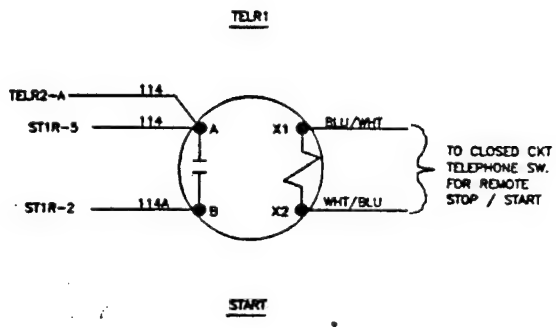
①



ST2R



ST1R



| QUANTITY FOR EACH ASSEMBLY                                                                                                                                                                                                             |            | ITEM NO.              | PART NO.   |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------|-----------------------|------------|
| <p>UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN FEET AND/OR INCHES</p> <p>TOLERANCES:</p> <p>JE DECIMALS</p> <p>JOE DECIMALS</p> <p>JOOD DECIMALS</p> <p>FRACTIONS <math>\pm 1/16"</math></p> <p>ANGLES <math>\pm 0.5^\circ</math></p> |            | PROD. NO.             | 966A- DF   |
|                                                                                                                                                                                                                                        |            | DATE                  | 10/17/1958 |
|                                                                                                                                                                                                                                        |            | CHK. BY               | 10/17/1958 |
|                                                                                                                                                                                                                                        |            | BRANCH HEAD           | 10/17/1958 |
|                                                                                                                                                                                                                                        |            | DRY DR                | 10/17/1958 |
|                                                                                                                                                                                                                                        |            | SHIP TO               | 10/17/1958 |
|                                                                                                                                                                                                                                        |            | SHIP TO               | 10/17/1958 |
|                                                                                                                                                                                                                                        |            | SHIP TO               | 10/17/1958 |
|                                                                                                                                                                                                                                        |            | SHIP TO               | 10/17/1958 |
|                                                                                                                                                                                                                                        |            | SHIP TO               | 10/17/1958 |
| PART DASH NO.                                                                                                                                                                                                                          | NEXT ASSY. | APPROVED              | DATE       |
|                                                                                                                                                                                                                                        |            | FOR COMMANDER, NAVFAC | SCALE      |

4

3

2

1

| REVISIONS |             |      |          |
|-----------|-------------|------|----------|
| NO        | DESCRIPTION | DATE | APPROVAL |
|           |             |      |          |

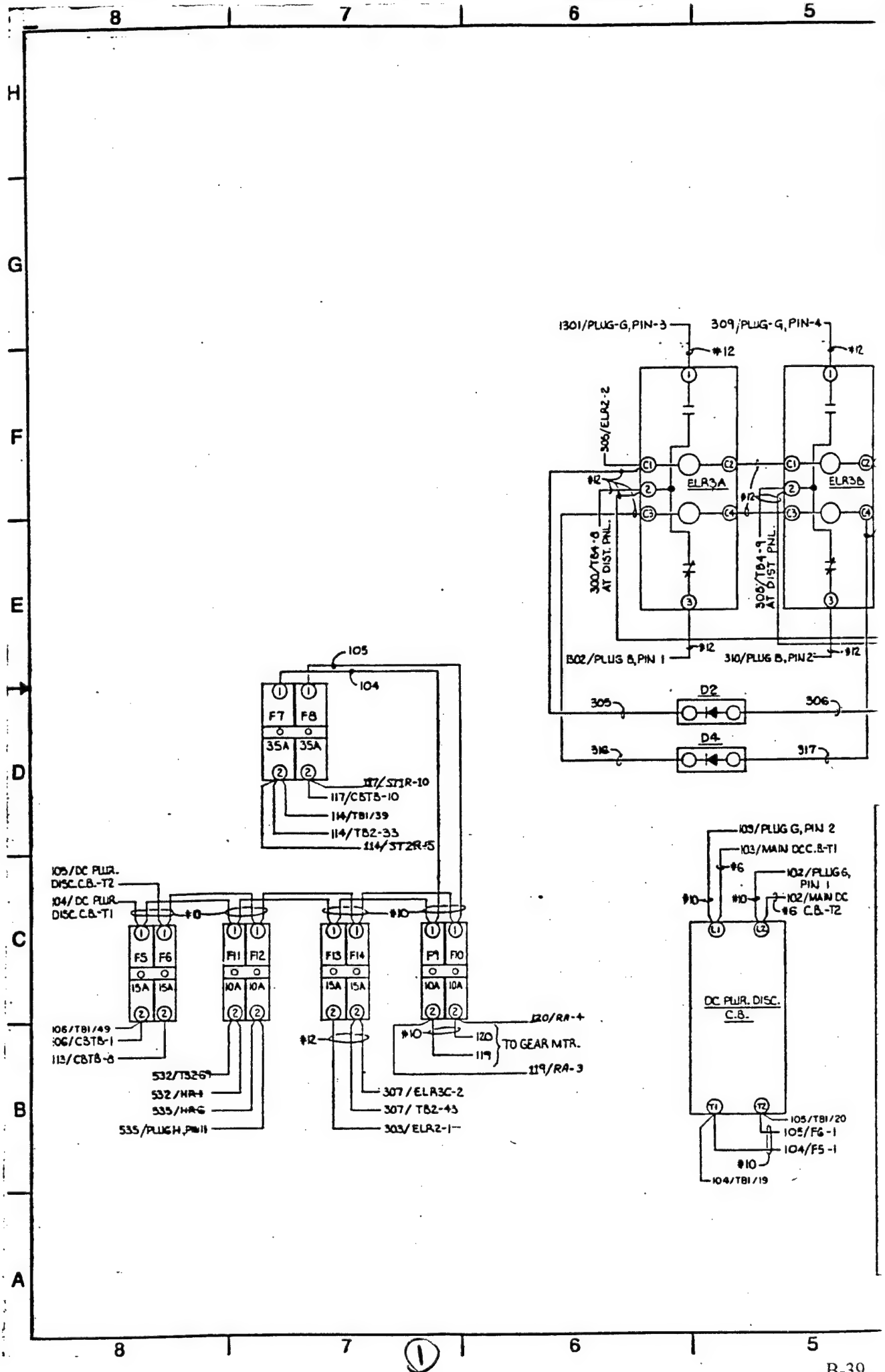
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 }  
 TO CLOSED CKT  
 TELEPHONE SW.  
 FOR REMOTE  
 STOP / START  
 WHY/BLU

BLU/WHY  
 }  
 TO CLOSED CKT  
 TELEPHONE SW.  
 FOR REMOTE  
 STOP / START  
 WHY/BLU

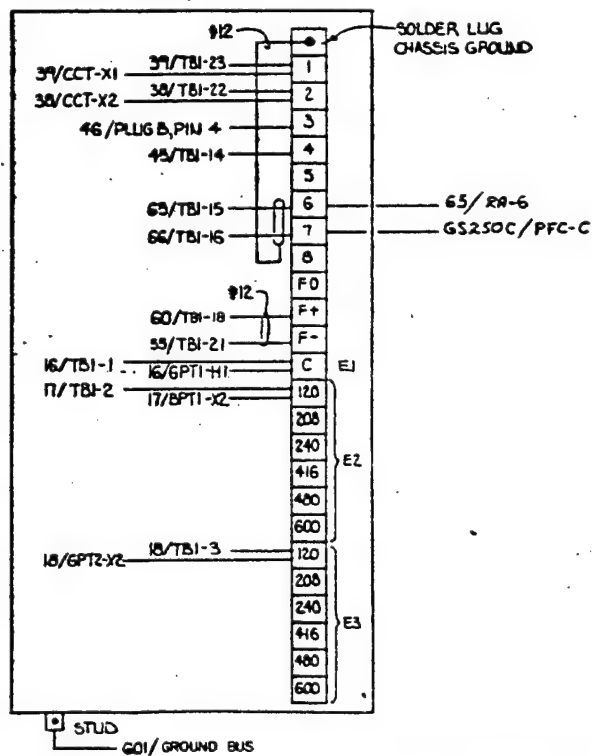
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|---------------------------------------------------------------------------------------------------|------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------|-------------|--------------------|
| QUANTITY FOR EACH ASSEMBLY                                                                        |            | ITEM NO.                                                                                                                                                                                                                                                              | PART NO. | DESCRIPTION | MATERIAL           |
| UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN FEET AND/OR INCHES                                   |            | PARTS LIST                                                                                                                                                                                                                                                            |          |             |                    |
| TOLERANCES:                                                                                       |            | PROJECT NO. 966A-DF<br>DRAWING NO. 966A-DF<br>DES. BY DR. F. DELALBERA<br>CHK. BY<br>BRANCH HEAD R. MACK<br>DW. BY<br>SATISFACTORY TO<br>NAME CHILDERS<br>APPROVED BY J. MORTON HELGESON DEC. 1988<br>APPROVED OFFICER DATE<br>APPROVED DATE<br>FOR COMMANDER, NAVFAC |          |             |                    |
| 1/8 DECIMALS<br>1/16 DECIMALS<br>1/32 DECIMALS<br>FRACTIONS $\pm 1/16"$<br>ANGLES $\pm 0.5^\circ$ |            | GOVERNMENT OF THE SHIP<br>NAVAL FACILITIES ENGINEERING SERVICE CENTER<br>PORT HUENEME, CALIFORNIA 93043<br>DUEL FUEL 1500 KW<br>CONVERSION OF DIESEL POWER PLANTS<br>METERING CUBICLE, RIGHT WALL                                                                     |          |             |                    |
| PART DASH NO.                                                                                     | NEXT ASSY. | SIZE                                                                                                                                                                                                                                                                  | CODE     | IDENT NO.   | NAVFAC DRAWING NO. |
|                                                                                                   |            |                                                                                                                                                                                                                                                                       | F        | 80091       |                    |
|                                                                                                   |            | SCALE                                                                                                                                                                                                                                                                 | INCHES   | SPEC        | SHEET 1 OF         |

✓ DOUBT, ASK - DO NOT SCALE

3

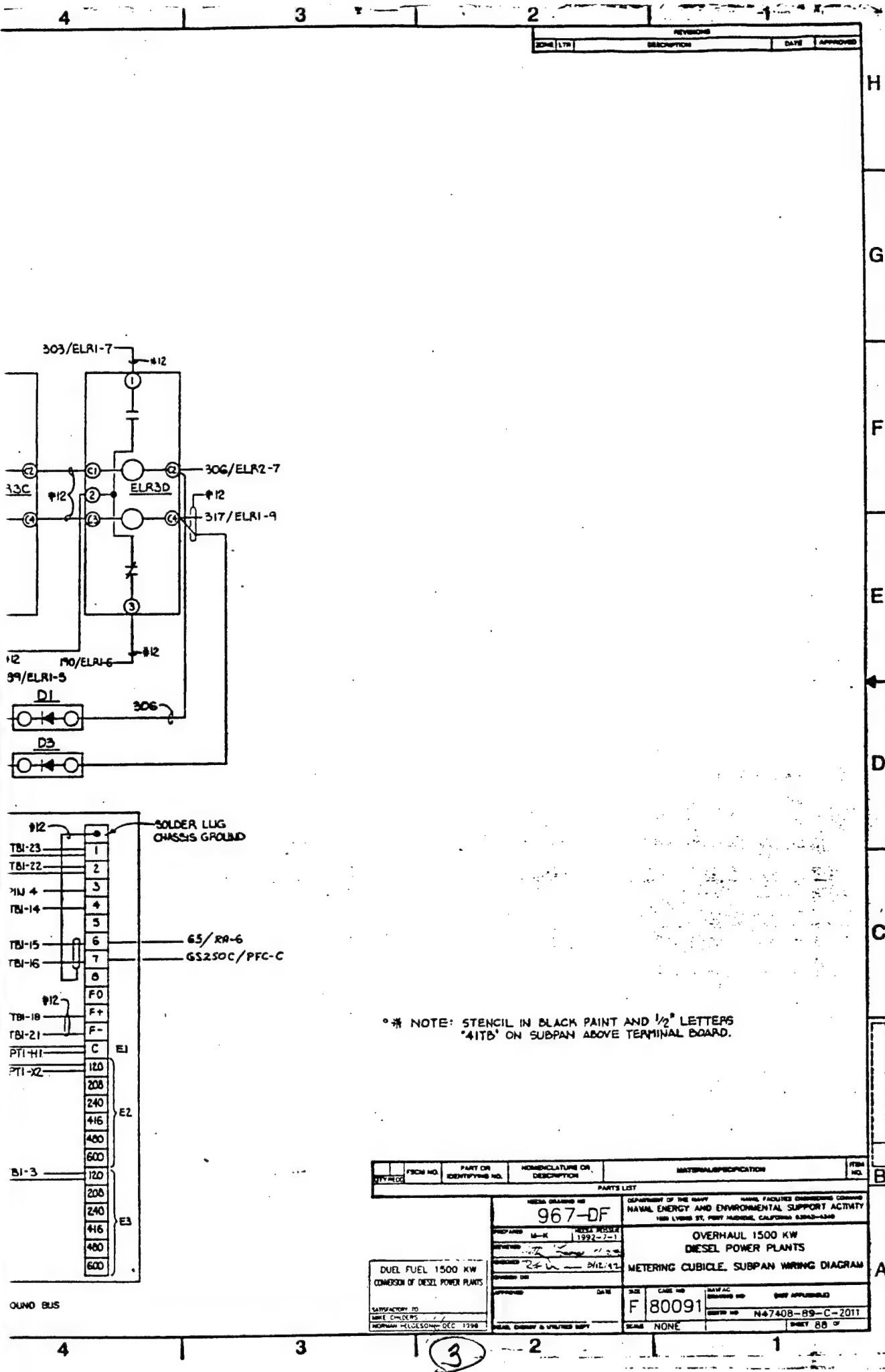




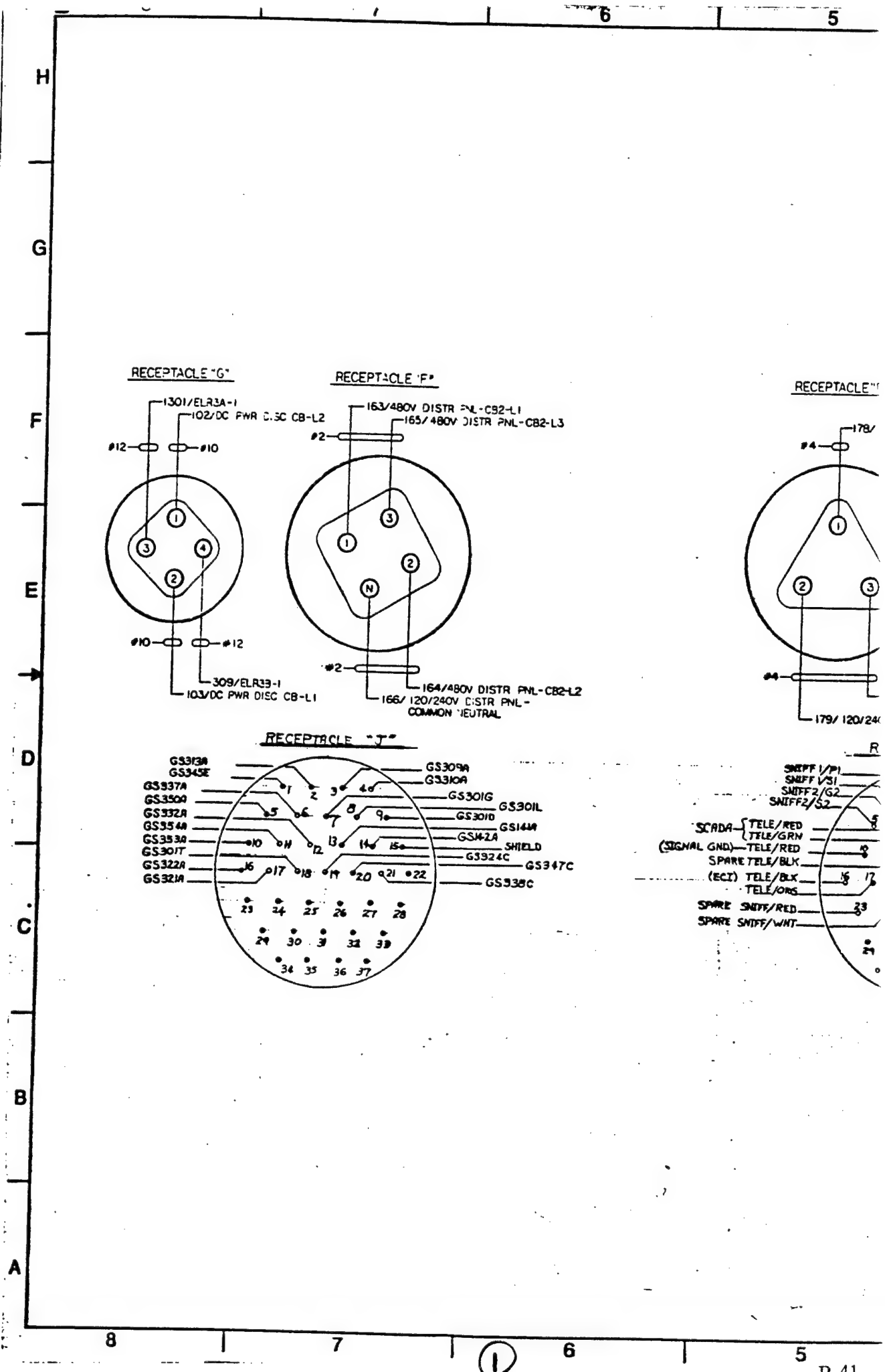


° \* NOTE: STENCIL IN BLACK PAINT AND 1/2" L  
"4ITB" ON SUBPAN ABOVE TERMINAL

|                                                  |                         |                                                                                                                                                               |      |
|--------------------------------------------------|-------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------|------|
| FORM NO.                                         | PART OR IDENTIFYING NO. | NOMENCLATURE OR DESCRIPTION                                                                                                                                   | DATE |
| PARTS LIST                                       |                         | REMARKS                                                                                                                                                       |      |
| DUEL FUEL 1500 KW COMBOSN OF DIESEL POWER PLANTS |                         | NEEDS GRATING NO. 967-DF<br>DEPARTMENT OF THE NAVAL ENGINEERING<br>1992-7-1<br>M-K<br>246 - 216.42<br>METERING C<br>DATE<br>SIZE CASE NO<br>800<br>SCALE NONE |      |
| SATISFACTORY TO UNIT COMMANDER                   |                         | NORMAL DELIVERY & UTILITIES DEPT                                                                                                                              |      |
| NORMAN HELGESON DEC 1998                         |                         |                                                                                                                                                               |      |



|                                                                                              |  |                         |  |                                                                                                                                  |  |                        |  |                |  |
|----------------------------------------------------------------------------------------------|--|-------------------------|--|----------------------------------------------------------------------------------------------------------------------------------|--|------------------------|--|----------------|--|
| FROM NO.                                                                                     |  | PART OR IDENTIFYING NO. |  | NOMENCLATURE OR DESCRIPTION                                                                                                      |  | MATERIAL SPECIFICATION |  | ITEM NO.       |  |
| PARTS LIST                                                                                   |  |                         |  |                                                                                                                                  |  |                        |  |                |  |
| DESIG. NO. 967-DF<br>PREPARED BY M-E<br>REVIEWED BY M-E<br>CHECKED BY M-E<br>APPROVED BY M-E |  |                         |  | DEPARTMENT OF THE NAVY<br>NAVAL ENERGY AND ENVIRONMENTAL SUPPORT ACTIVITY<br>1000 LIVING ST., PORT HARBOR, CALIFORNIA 92043-4340 |  |                        |  |                |  |
| DUEL FUEL 1500 KW<br>CONVERSION OF DIESEL POWER PLANTS                                       |  |                         |  | OVERHAUL 1500 KW<br>DIESEL POWER PLANTS<br>METERING CUBICLE, SUBPAN WIRING DIAGRAM                                               |  |                        |  |                |  |
| SATISFACTORY TO: NORMAN HELGASON DEC 1998                                                    |  |                         |  | DATE:                                                                                                                            |  | SIZE: F                |  | CASE NO: 80091 |  |
| SCALE: NONE                                                                                  |  |                         |  | DATE:                                                                                                                            |  | NAVJAC:                |  | SHEET 86 OF    |  |

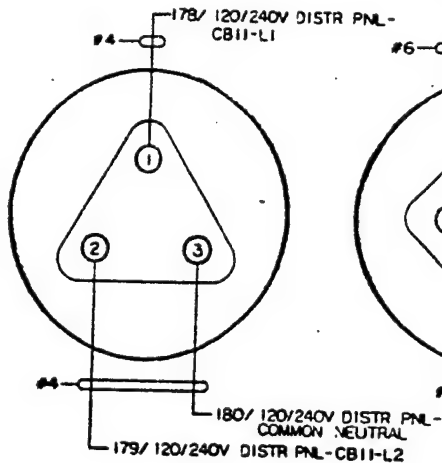


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547/TB2-63-  
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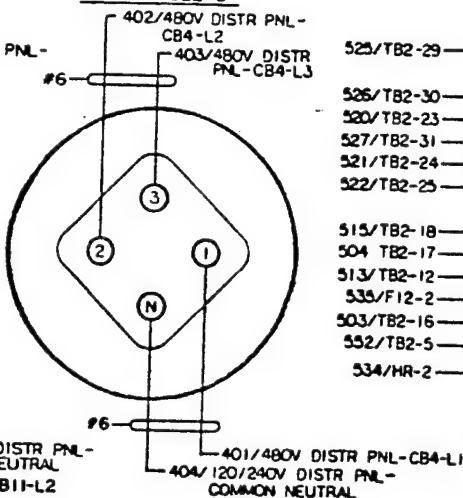
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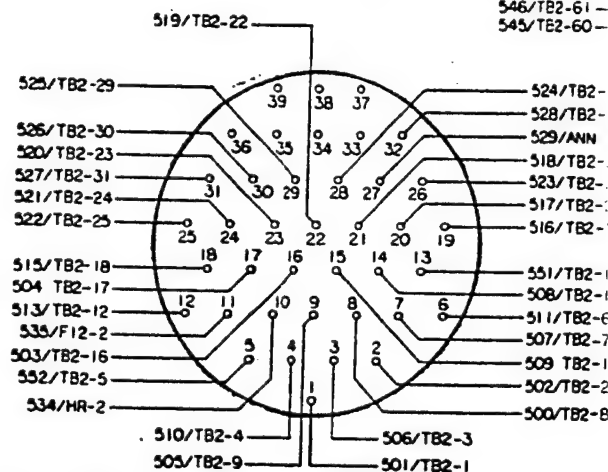
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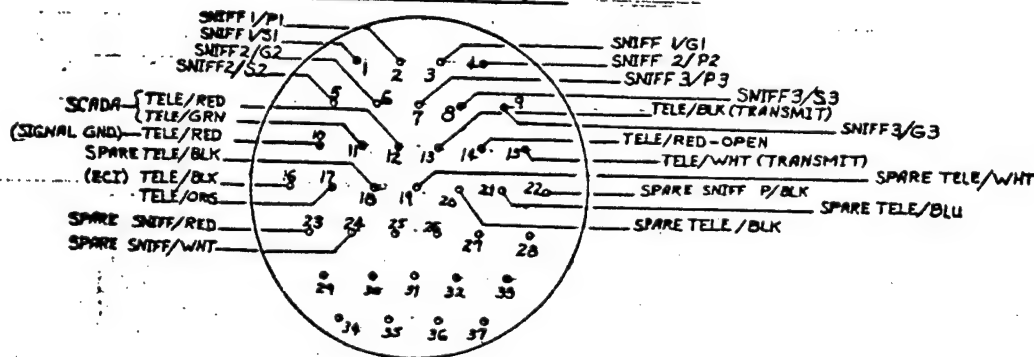
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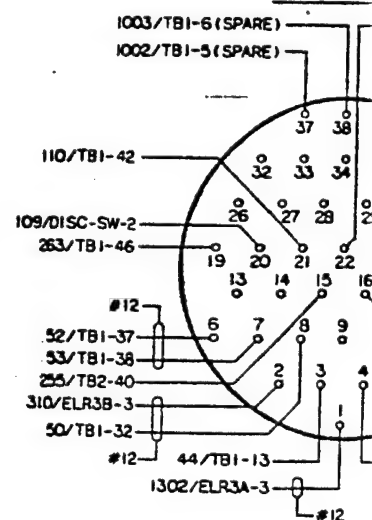
RECEPTACLE "H"



RECEPTACLE "S"



RECEPTACLE "I"



| REV                                                           | FROM NO | PART OR IDENTIFYING NO | NOMENCLATURE OR DESCRIPTION | PARTS |
|---------------------------------------------------------------|---------|------------------------|-----------------------------|-------|
| 1                                                             |         |                        |                             |       |
| 969-DF                                                        |         |                        |                             |       |
| DUEL FUEL 1500 KW<br>COMMON OF DIESEL POWER PLANTS            |         |                        |                             |       |
| SATISFACTORY TO<br>MR. CHILDERS<br>NORMAN HELGESON / DEC 1998 |         |                        |                             |       |
| REVISION OR                                                   |         |                        |                             |       |
| APPROVED                                                      |         |                        |                             |       |
| REASON, CHANGE & DATE                                         |         |                        |                             |       |

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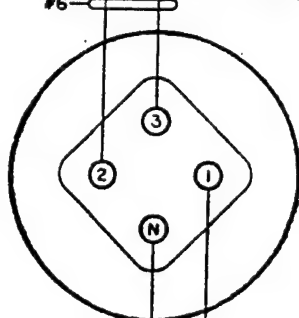
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| REVISIONS |     |             |          |
|-----------|-----|-------------|----------|
| ZONE      | LTN | DESCRIPTION | DATE     |
|           |     |             | APPROVED |

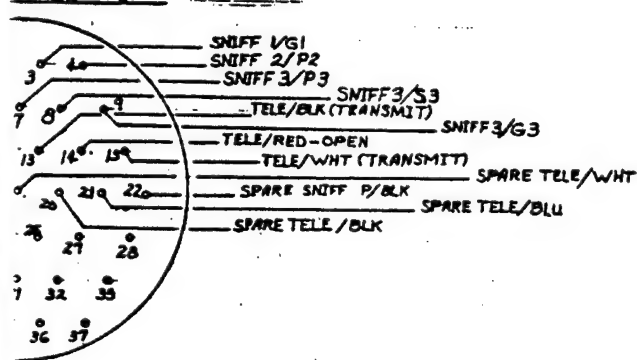
RECEPTACLE "C"

402/480V DISTR PNL-  
CB4-L2  
403/480V DISTR  
PNL-CB4-L3

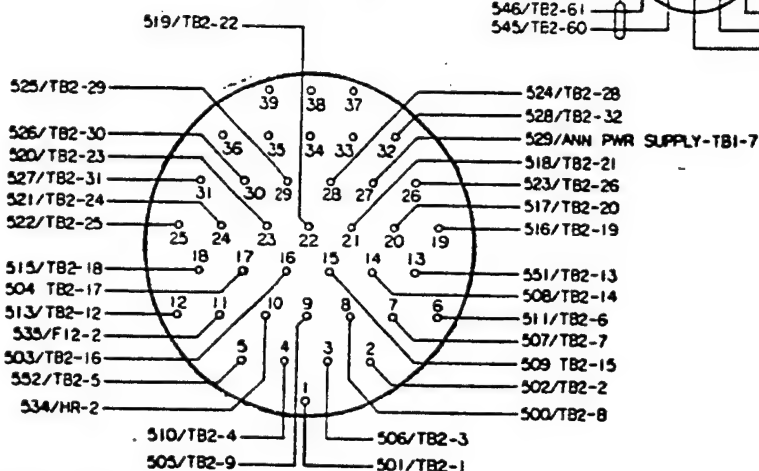


3/240V DISTR PNL-  
COMMON NEUTRAL  
9 PNL-CB11-L2  
401/480V DISTR PNL-CB4-L1  
404/120/240V DISTR PNL-  
COMMON NEUTRAL

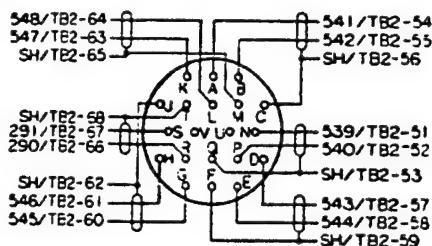
TABLE "S"



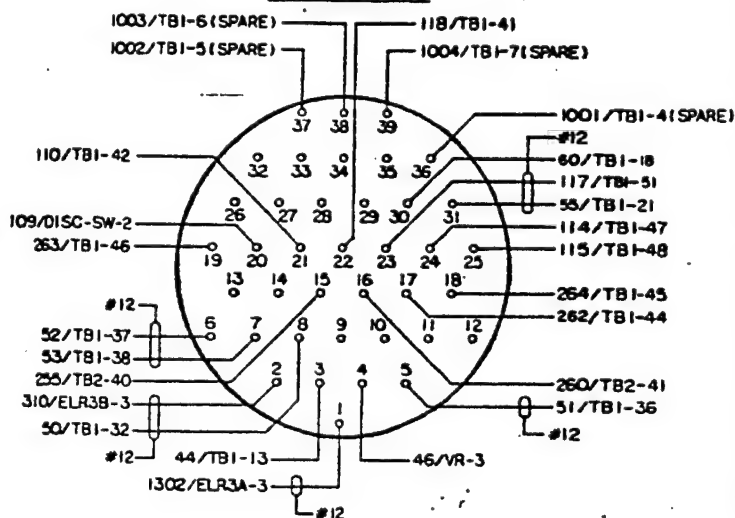
RECEPTACLE "H"



RECEPTACLE "A"



RECEPTACLE "B"



|                                                                                                 |                         |                                                                                                                               |                        |          |
|-------------------------------------------------------------------------------------------------|-------------------------|-------------------------------------------------------------------------------------------------------------------------------|------------------------|----------|
| FORM NO.                                                                                        | PART OR IDENTIFYING NO. | NOMENCLATURE OR DESCRIPTION                                                                                                   | MATERIAL SPECIFICATION | ITEM NO. |
| PARTS LIST                                                                                      |                         |                                                                                                                               |                        |          |
| 969-DF                                                                                          |                         | DEPARTMENT OF THE NAVY<br>NAVAL ENERGY AND ENVIRONMENTAL SUPPORT ACTIVITY<br>1081 LYONS ST. PORT HADEN, CALIFORNIA 93933-4330 |                        |          |
| OVERHAUL 1500 KW<br>DIESEL POWER PLANTS<br>METERING CUBICLE<br>CABLE RECEPTACLES WIRING DIAGRAM |                         | SEE APPROPRIATE                                                                                                               |                        |          |
| F 80091                                                                                         |                         | N47408-89-C-2011                                                                                                              |                        |          |
| NONE                                                                                            |                         | SHEET 90 OF                                                                                                                   |                        |          |

4

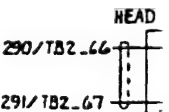
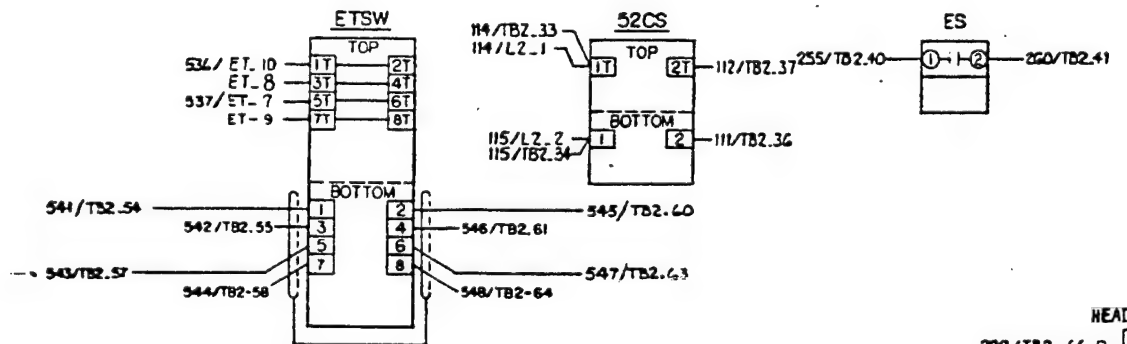
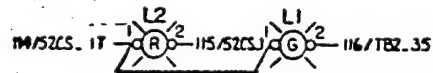
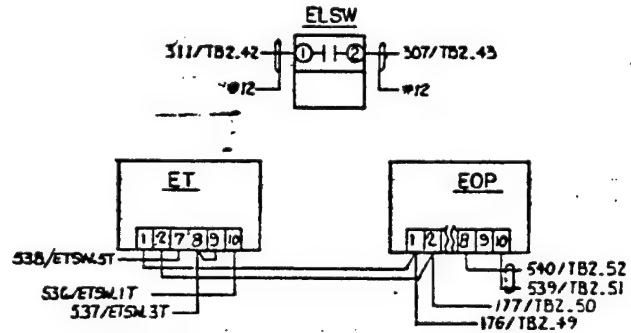
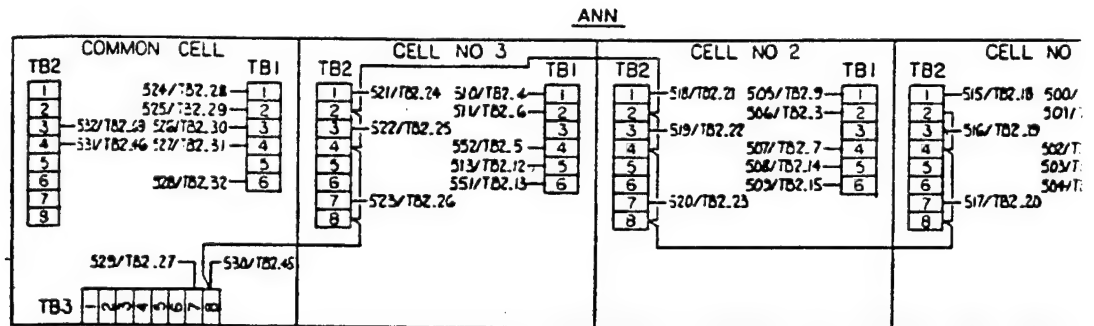
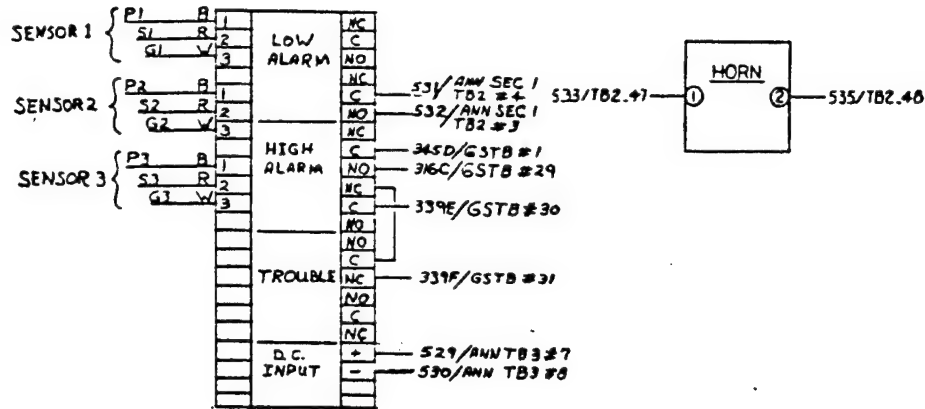
3

3

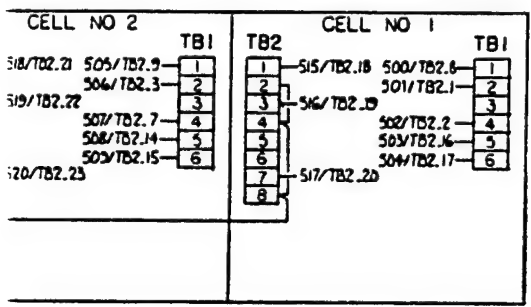
2

1

# LEAK DETECTION SYSTEM CONTROLLER

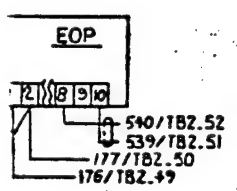


535/TB2.48

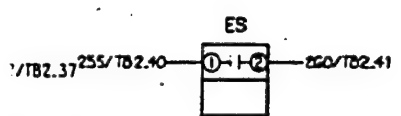


07/TB2.43

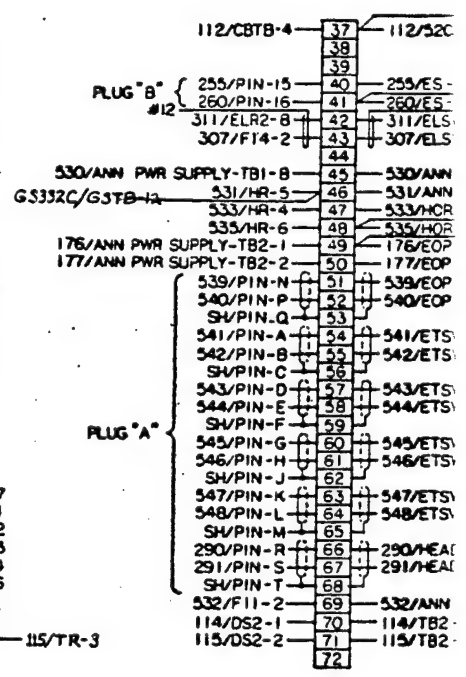
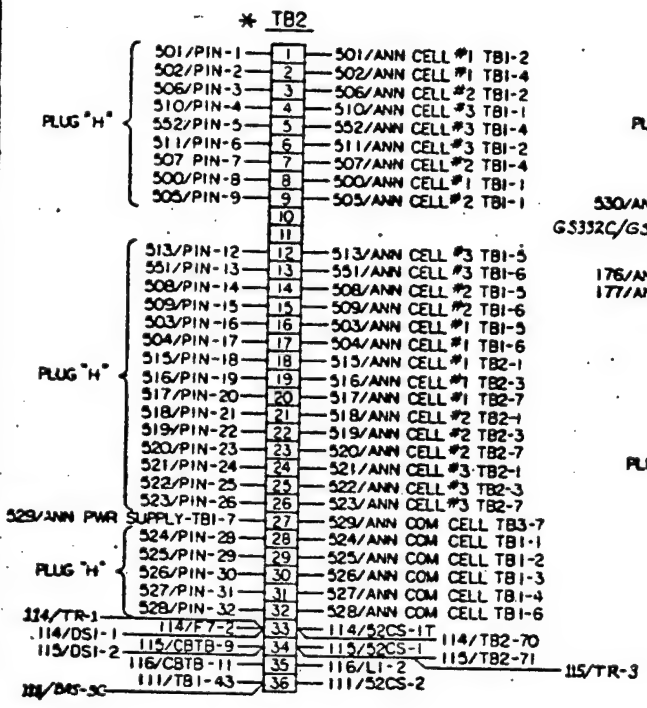
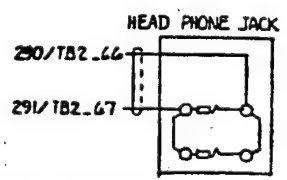
12



116/TB2.35



TB2.36

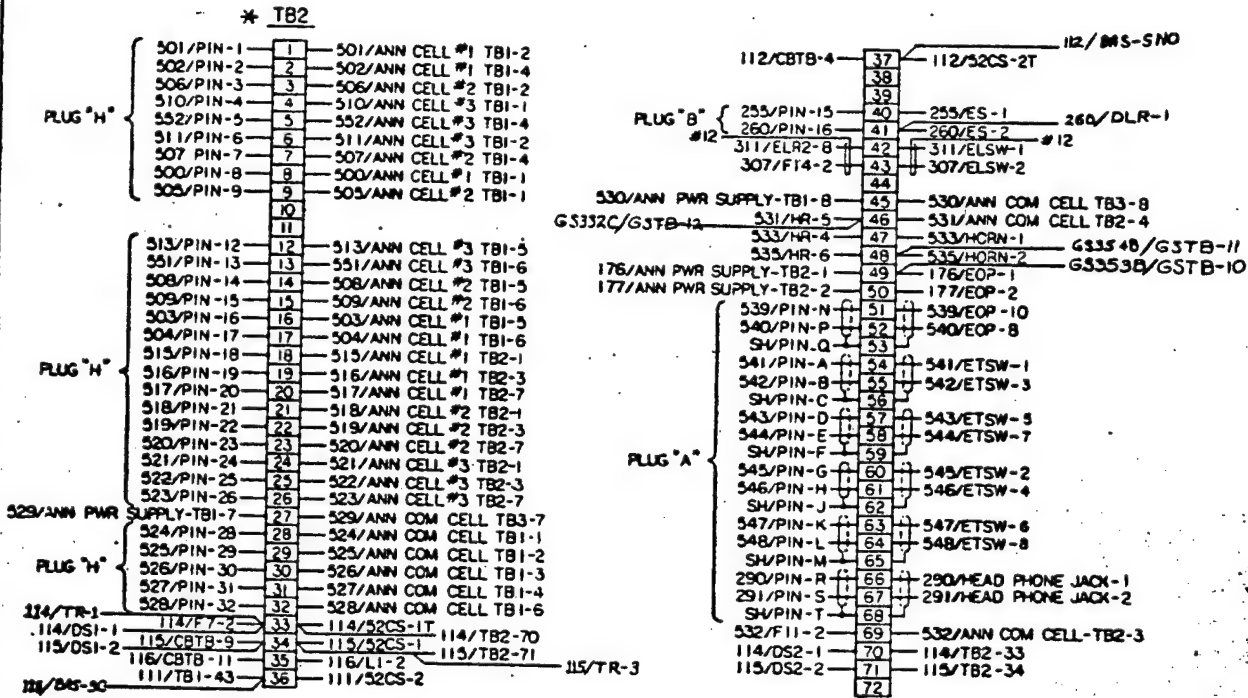


\* NOTE: STENCIL IN BLACK PAINT AND "TB2" ON SUBPAN ABOVE TERM

|                                                     |                         |                             |                            |
|-----------------------------------------------------|-------------------------|-----------------------------|----------------------------|
| FROM NO.                                            | PART OR IDENTIFYING NO. | NOMENCLATURE OR DESCRIPTION | PARTS LIST                 |
| 970-OF                                              |                         |                             | DEPARTMENT OF NAVAL ENERGY |
| DUEL FUEL 1500 KW CONVERSION OF DIESEL POWER PLANTS |                         |                             | SCALE NCNE                 |
| SATISFACTORY TO: [Signature]                        |                         |                             | DATE: [Date]               |
| NORMAL (ECCO) DEC 1964                              |                         |                             | SCALE: 1/8" = 1"           |

| REVISIONS (CONTINUED) |             |      |         | REVISIONS |             |      |          |
|-----------------------|-------------|------|---------|-----------|-------------|------|----------|
| DATE                  | DESCRIPTION | DATE | APPROVE | DATE      | DESCRIPTION | DATE | APPROVED |

|     |
|-----|
| TBI |
| 1   |
| 2   |
| 3   |
| 4   |
| 5   |
| 6   |



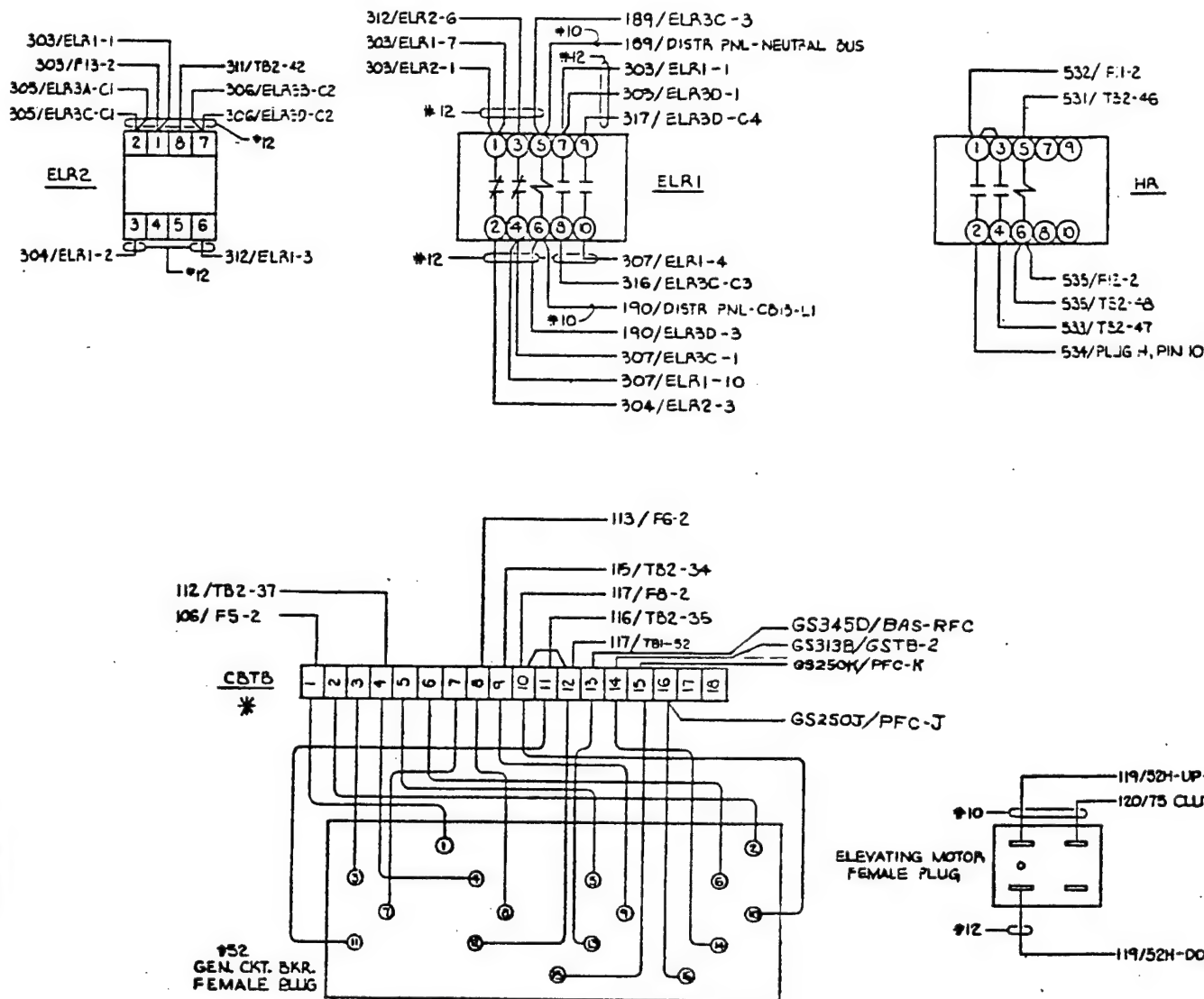
\* NOTE: STENCIL IN BLACK PAINT AND 1/2" LETTERS  
 "TB2" ON SUBPAN ABOVE TERMINAL BOARD.



|                                                                                                                       |          |                         |                                                                                                                                 |                        |          |
|-----------------------------------------------------------------------------------------------------------------------|----------|-------------------------|---------------------------------------------------------------------------------------------------------------------------------|------------------------|----------|
| CITY/CO                                                                                                               | FROM NO. | PART OR IDENTIFYING NO. | NOMENCLATURE OR DESCRIPTION                                                                                                     | MATERIAL/SPECIFICATION | ITEM NO. |
| PARTS LIST                                                                                                            |          |                         |                                                                                                                                 |                        |          |
| DESK DRAWING NO.<br><div style="font-size: 1.2em; font-weight: bold;">970-DF</div>                                    |          |                         | DEPARTMENT OF THE NAVY<br>NAVAL ENERGY AND ENVIRONMENTAL SUPPORT ACTIVITY<br>1101 LYNCH ST. PORT HUENEME, CALIFORNIA 94943-4348 |                        |          |
| PREPARED BY: M-K<br>CHECKED BY: JLS<br>DESIGNED BY: JLS<br>APPROVED BY: JLS                                           |          |                         | OVERHAUL 1500 KW<br>DIESEL POWER PLANTS<br>CIRCUIT BREAKER CUBICLE<br>DOOR WIRING DIAGRAM                                       |                        |          |
| DUEL FUEL 1500 KW<br>COMMISSION OF DIESEL POWER PLANTS<br>Satisfactory to:<br>WIRE CHIEFS<br>NORMAN WELCHSON DEC 1998 |          |                         | SCALE: NCNE<br>DRAWING NO: F 80091<br>CONTROL NO: N47408-89-C-2011<br>SHEET 91 OF                                               |                        |          |



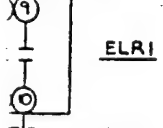
**A**



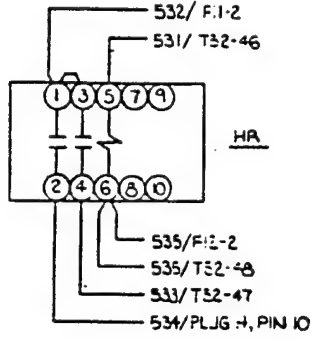
\* NOTE: STENCIL IN BLACK FOR "CBTB" ON SUBPANEL

| FIGURE NO.                                           | PART OR IDENTIFYING NO. | NOMENCLATURE OR DESCRIPTION | PARTS LIST |
|------------------------------------------------------|-------------------------|-----------------------------|------------|
| 971-DF                                               |                         |                             |            |
| PREPARED BY: M-K                                     | 1997-1-1                |                             |            |
| CHECKED BY: M-K                                      |                         |                             |            |
| APPROVED BY: M-K                                     |                         |                             |            |
| DUEL FUEL 1500 KW COMBINATION OF DIESEL POWER PLANTS |                         |                             |            |
| SABOTAGE TO: M-K CHILDERS                            |                         |                             |            |
| NORMAN HELGESON "DEC" 1998                           |                         |                             |            |
| DATE: 1997-1-1                                       |                         |                             |            |
| REVISION: 1                                          |                         |                             |            |
| F                                                    |                         |                             |            |

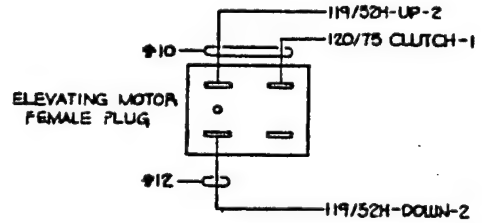
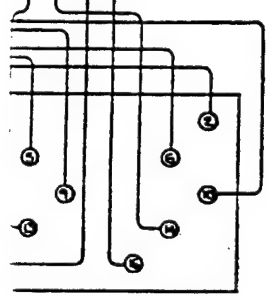
10- 189/ELR3C-3  
 12- 189/DISTR PNL-NEUTRAL BUS  
 303/ELR1-1  
 305/ELR3D-1  
 317/ELR3D-C4



307/ELR1-4  
 316/ELR3C-C3  
 190/DISTR PNL-CB15-L1  
 190/ELR3D-3  
 307/ELR3C-1  
 307/ELR1-10  
 304/ELR2-3



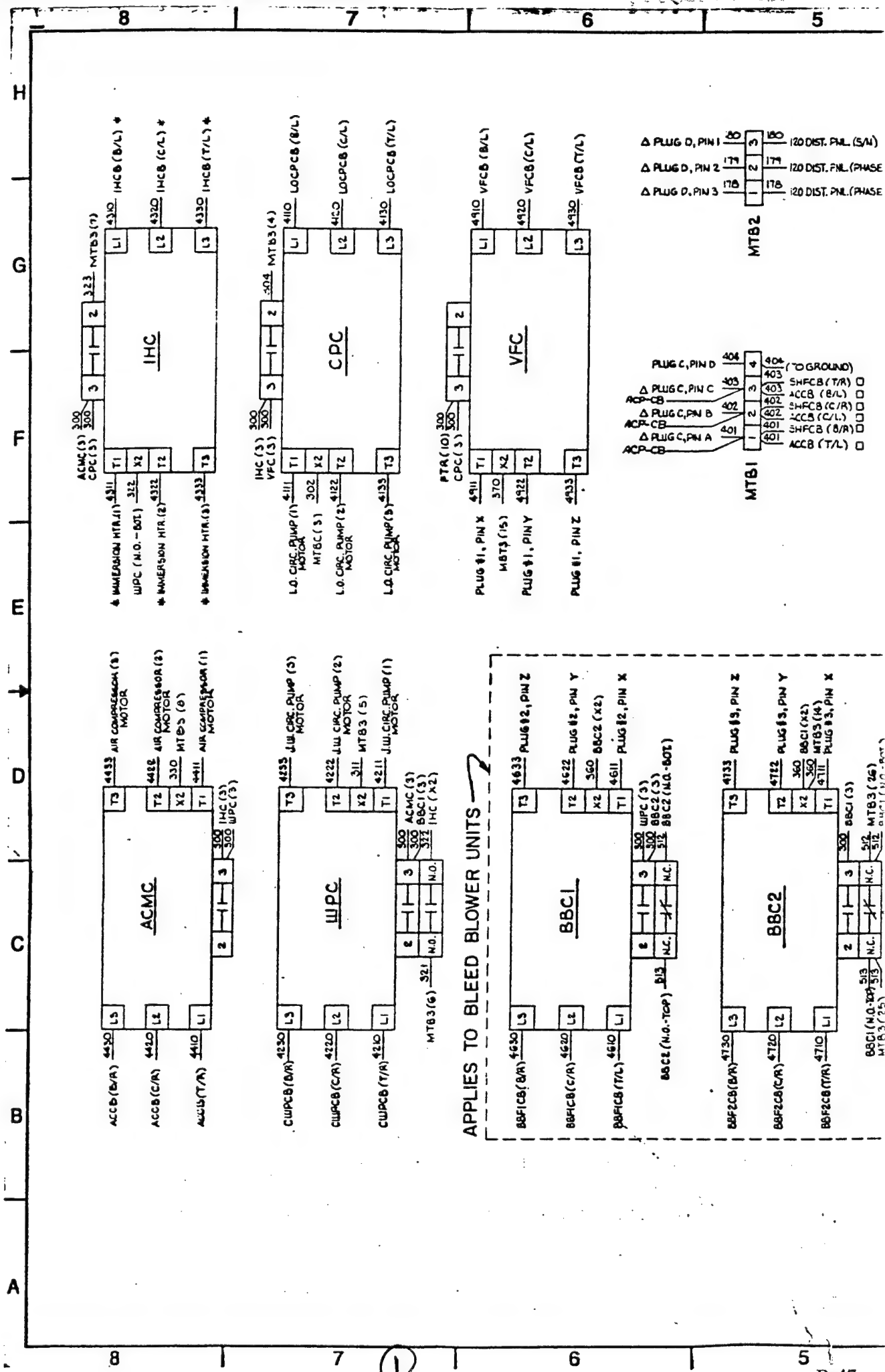
113/F6-2  
 115/TB2-34  
 117/F8-2  
 116/TB2-35  
 117/TB1-52  
 GS345D/BAS-RFC  
 GS313B/GSTB-2  
 GS250K/PFC-K  
 GS250J/PFC-J



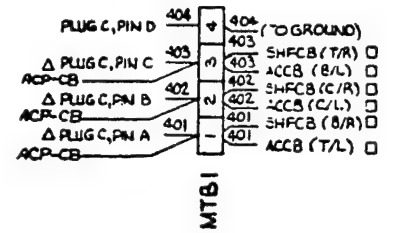
\* NOTE: STENCIL IN BLACK PAINT AND 1/8" LETTERS  
 "CBTB" ON SUBPAN NEXT TO TERMINAL BOARD.

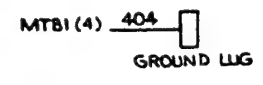
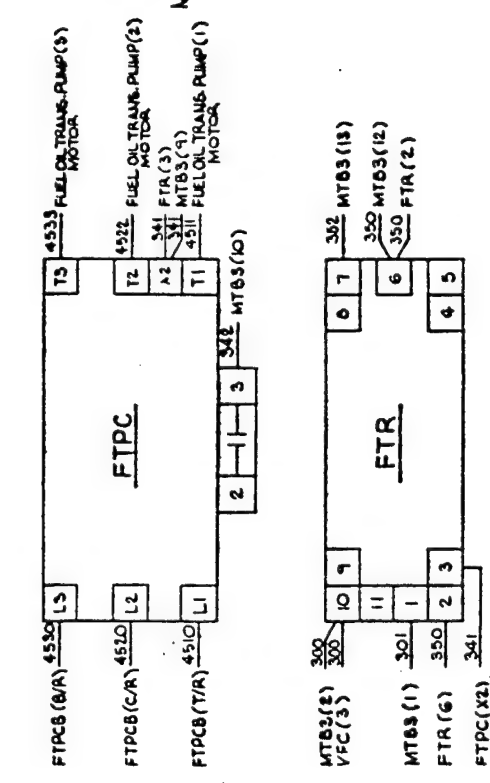
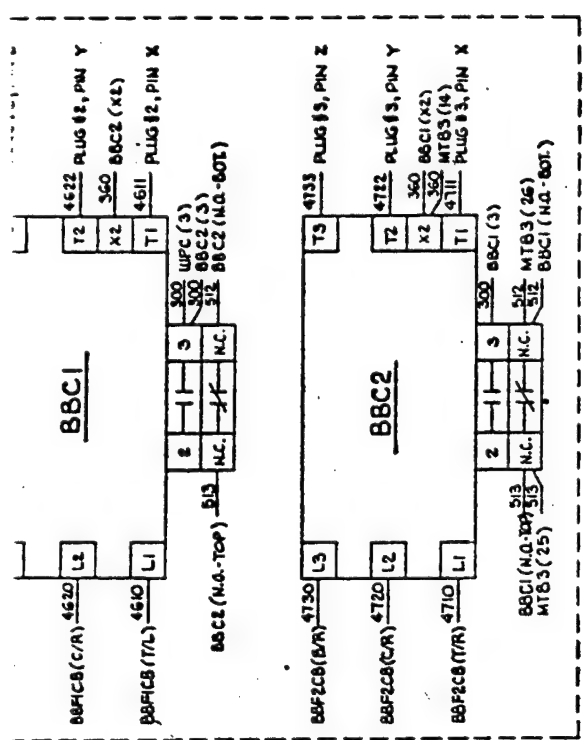
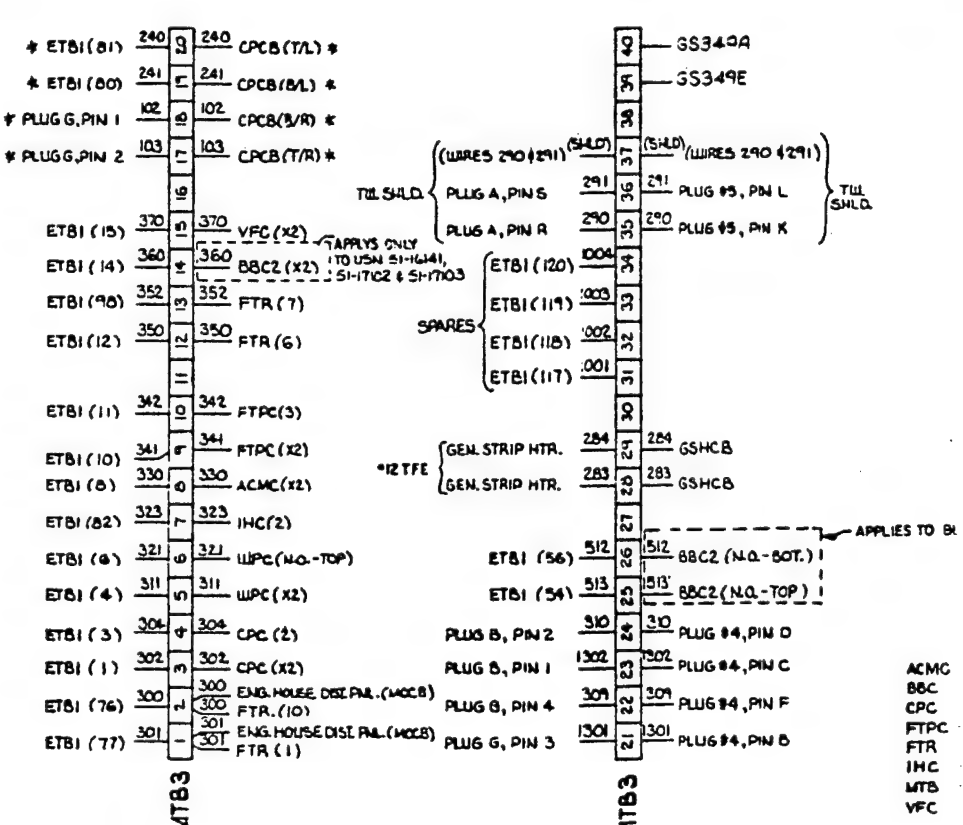
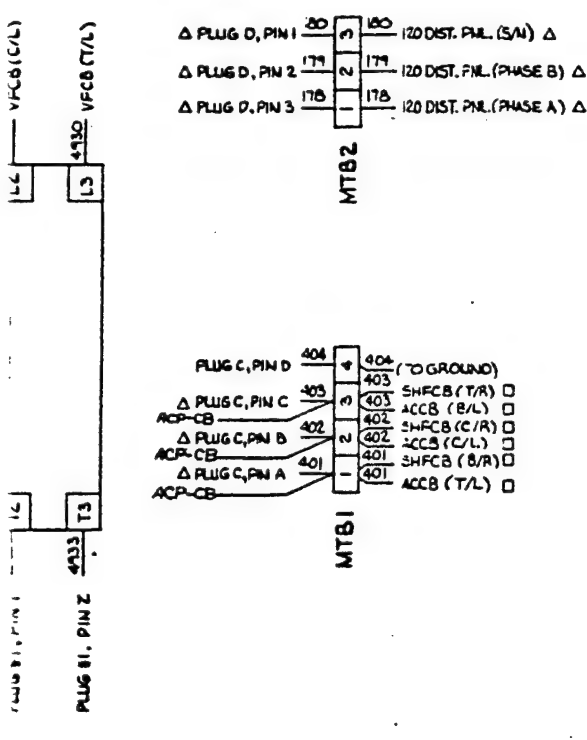
|                                                                                                                         |          |                         |                                                                                                                                                                        |                        |          |
|-------------------------------------------------------------------------------------------------------------------------|----------|-------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------|----------|
| SYMBOL                                                                                                                  | 13CN NO. | PART OR IDENTIFYING NO. | NOMENCLATURE OR DESCRIPTION                                                                                                                                            | MATERIAL SPECIFICATION | ITEM NO. |
| PARTS LIST                                                                                                              |          |                         |                                                                                                                                                                        |                        |          |
| MEDIA BRANDING NO.<br><b>971-DF</b><br>M-K<br>1992-11-1                                                                 |          |                         | DEPARTMENT OF THE NAVY<br>NAVAL FACILITIES ENGINEERING COMMAND<br>NAVAL ENERGY AND ENVIRONMENTAL SUPPORT ACTIVITY<br>100 LYONS ST. PORT HUEBNER, CALIFORNIA 92040-4340 |                        |          |
| DUEL FUEL 1500 KW<br>CONVERSION OF DIESEL POWER PLANTS<br>SATISFACTORY TO<br>NAME CHILDERS<br>NORMAN MELGSON "DEC" 1998 |          |                         | OVERHAUL 1500 KW<br>DIESEL POWER PLANTS<br>CIRCUIT BREAKER CUBICLE<br>SUBPAN WIRING DIAGRAM                                                                            |                        |          |
| APPROVED<br>DATE<br>DESIGNED BY<br>SCALE NONE                                                                           |          |                         | CASE NO.<br><b>F 80091</b><br>DRAWING NO.<br><b>N47408-99-C-2011</b><br>SHEET 92 OF                                                                                    |                        |          |

3



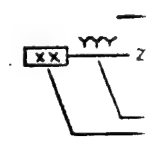
Δ PLUG D, PIN 1 120 DIST. PNL (S/A)  
Δ PLUG D, PIN 2 120 DIST. PNL (PHASE)  
Δ PLUG D, PIN 3 120 DIST. PNL (PHASE)



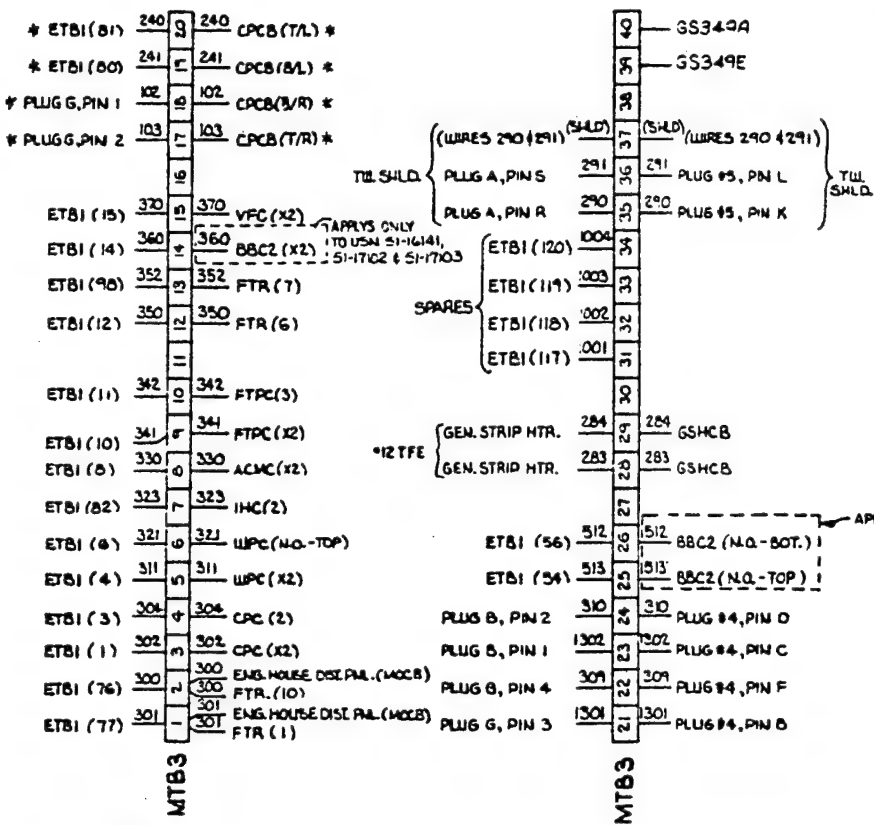


NOTES:

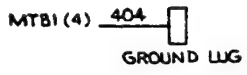
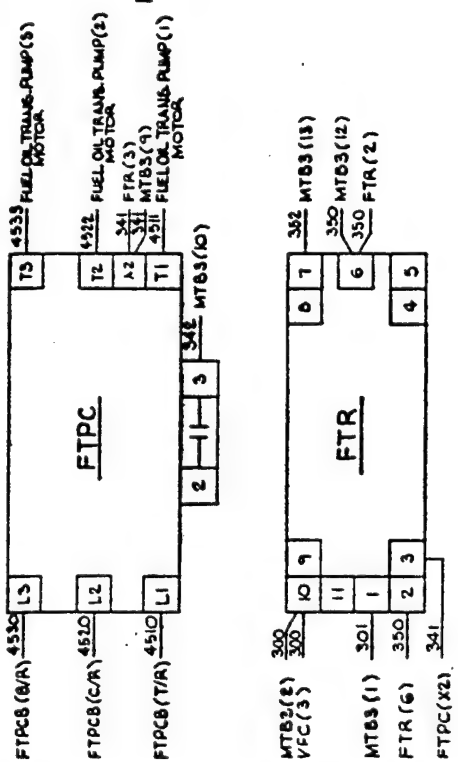
1. UNLESS
2. \* - USE
3. □ - USE
4. Δ - USE



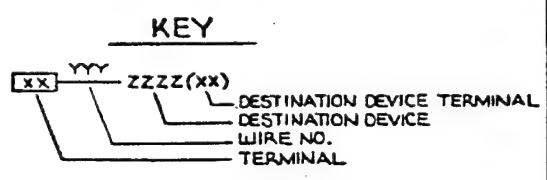
|                                                           |       |
|-----------------------------------------------------------|-------|
| DESIGN NO.                                                | 988-1 |
| PROPOSED BY                                               | DATE  |
| REVIEWED BY                                               | DATE  |
| APPROVED BY                                               | DATE  |
| DUEL FUEL 1500 KW<br>CONVERSION OF DIESEL POWER PLANTS    |       |
| SUPERVISOR TO<br>LINE CHIEFS<br>NORMAN HELGESON DEC. 1998 |       |



- ### LEGEND
- ACMG - AIR COMPRESSOR MOTOR CONTROLLER
  - BBC - BLEED BLOWER CONTROLLER
  - CPC - CIRCULATING PUMP CONTROLLER
  - FTPC - FUEL TRANSFER PUMP CONTROLLER
  - FTR - FUEL TRANSFER RELAY
  - IHC - IMMERSION HEATER CONTROLLER
  - MTB - MOTOR CONTROL CENTER TERMINAL BLOCK
  - VFC - VENTILATION FAN CONTROLLER



- ### NOTES:
1. UNLESS OTHERWISE NOTED USE #12 AWG 515 GRAY WIRE.
  2. \* - USE #10 AWG 515 GRAY WIRE.
  3. □ - USE #8 AWG 515 GRAY WIRE.
  4. △ - USE #4 AWG 515 GRAY WIRE.



| QTY                                                                                                                                                                                                                                                                                                                         | FROM NO. | PART OR IDENTIFYING NO. | NOMENCLATURE OR DESCRIPTION | MATERIAL SPECIFICATION | ITEM NO. |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------|-------------------------|-----------------------------|------------------------|----------|
| PARTS LIST                                                                                                                                                                                                                                                                                                                  |          |                         |                             |                        |          |
| <div style="display: flex; justify-content: space-between;"> <div> <p>DESIGN NO. 988-DF</p> <p>PREPARED BY: J. K. 1992-7-1</p> <p>CHECKED BY: J. K. 8-17-92</p> <p>APPROVED BY: J. K. 8-17-92</p> </div> <div> <p>OVERHAUL 1500 KW DIESEL POWER PLANTS CONNECTION DIAGRAM, MOTOR CONTROL CENTER</p> </div> </div>           |          |                         |                             |                        |          |
| <div style="display: flex; justify-content: space-between;"> <div> <p>DUEL FUEL 1500 KW COMBOSION OF DIESEL POWER PLANTS</p> <p>SAFETY TO: 1/1</p> <p>WIRE CHECKS: 1/1</p> <p>NOTATION: 1/1</p> </div> <div> <p>DATE: 8-17-92</p> <p>BY: J. K.</p> </div> <div> <p>REVISION NO. 1</p> <p>DESCRIPTION: 1/1</p> </div> </div> |          |                         |                             |                        |          |
| <div style="display: flex; justify-content: space-between;"> <div> <p>APPROVED: J. K.</p> <p>DATE: 8-17-92</p> </div> <div> <p>REVISION NO. 1</p> <p>DESCRIPTION: 1/1</p> </div> </div>                                                                                                                                     |          |                         |                             |                        |          |
| <div style="display: flex; justify-content: space-between;"> <div> <p>APPROVED: J. K.</p> <p>DATE: 8-17-92</p> </div> <div> <p>REVISION NO. 1</p> <p>DESCRIPTION: 1/1</p> </div> </div>                                                                                                                                     |          |                         |                             |                        |          |

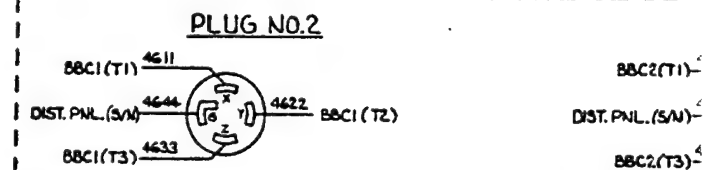
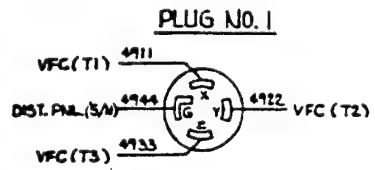
| JTBI                |      |    |                         |
|---------------------|------|----|-------------------------|
| PLUG NO. 7, PIN X   | 4611 | 1  | 4611 PLUG NO. 2, PIN X  |
| PLUG NO. 7, PIN Y   | 4622 | 2  | 4622 PLUG NO. 2, PIN Y  |
| PLUG NO. 7, PIN Z   | 4633 | 3  | 4633 PLUG NO. 2, PIN Z  |
| PLUG NO. 7, PIN G   | 4644 | 4  | 4644 PLUG NO. 2, PIN G  |
| PLUG NO. 8, PIN X   | 4711 | 5  | 4711 PLUG NO. 3, PIN X  |
| PLUG NO. 8, PIN Y   | 4722 | 6  | 4722 PLUG NO. 3, PIN Y  |
| PLUG NO. 8, PIN Z   | 4733 | 7  | 4733 PLUG NO. 3, PIN Z  |
| PLUG NO. 8, PIN G   | 4744 | 8  | 4744 PLUG NO. 3, PIN G  |
| EMERG. LT. SW. L.S. | 391  | 9  | 391 EMERG. LT. SW. R.S. |
| EMERG. LT. SW. L.S. | 392  | 10 | 392 EMERG. LT. SW. R.S. |
| AC LT. SW. L.S.     | 396  | 11 | 396 AC LT. SW. R.S.     |
| AC LT. SW. L.S.     | 397  | 12 | 397 AC LT. SW. R.S.     |

APPLIES TO BLEED BLOWER UNITS

| JT82                 |      |    |                        |
|----------------------|------|----|------------------------|
| SP. HTR. REAR (L1)   | 4810 | 1  | 4810 PLUG NO. 5, PIN A |
| SP. HTR. REAR (L2)   | 4820 | 2  | 4820 PLUG NO. 5, PIN B |
| SP. HTR. REAR (L3)   | 4830 | 3  | 4830 PLUG NO. 5, PIN C |
| SP. HTR. REAR (GRD.) | 4840 | 4  | 4840 PLUG NO. 5, PIN G |
| SP. HTR. FRT. (GRD.) | 4850 | 5  | 4850 PLUG NO. 5, PIN D |
| SP. HTR. FRT. (L1)   | 4860 | 6  | 4860 PLUG NO. 5, PIN E |
| SP. HTR. FRT. (L2)   | 4870 | 7  | 4870 PLUG NO. 5, PIN F |
| SP. HTR. FRT. (L3)   | 4880 | 8  |                        |
| PLUG NO. 6, PIN X    | 4911 | 9  | 4911 PLUG NO. 1, PIN X |
| PLUG NO. 6, PIN Y    | 4922 | 10 | 4922 PLUG NO. 1, PIN Y |
| PLUG NO. 6, PIN Z    | 4933 | 11 | 4933 PLUG NO. 1, PIN Z |
| PLUG NO. 6, PIN G    | 4944 | 12 | 4944 PLUG NO. 1, PIN G |

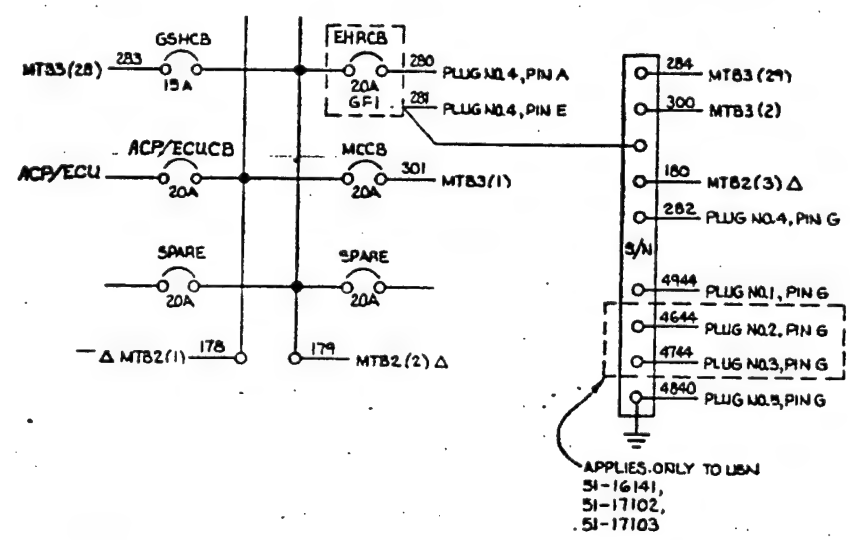
#18 TULSHLD.  
#10 TULSHLD.

### TERMINAL BOARDS ABOVE MOTOR CONTROL CEN

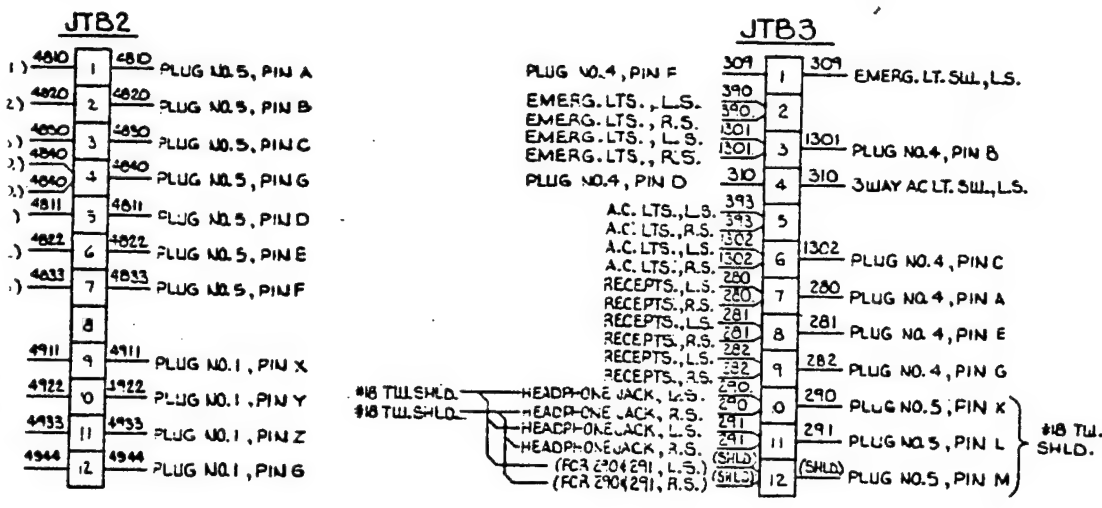


APPLIES TO BLEED BLOWER UNITS

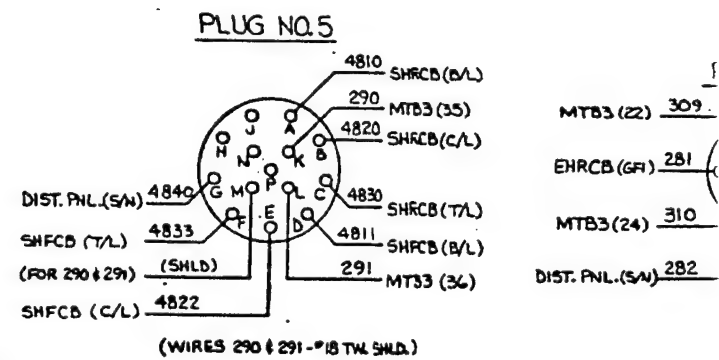
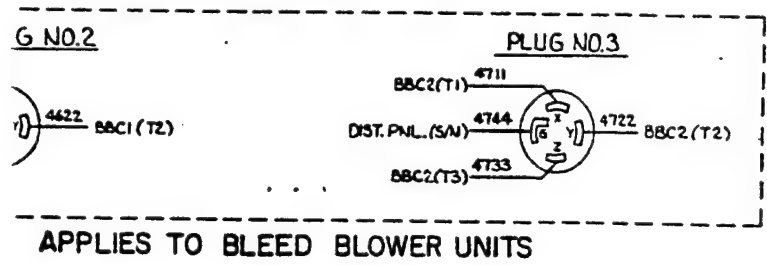
TOP OF DISTRIBUTION  
(VIEW)



### ENGINE HOUSE DISTRIBUTION PANEL 120/240 VAC

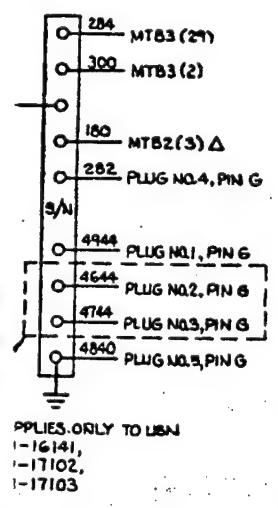


## ARDS ABOVE MOTOR CONTROL CENTER



## TOP OF DISTRIBUTION PANEL~RECEPTACLES

(VIEW FROM REAR)



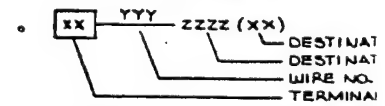
## LEGEND

- EHRCB - ENGINE HOUSE RECEPTACLE
- GSHCB - GENERATOR STRIP HEATER
- JTB1,2,3 - JUNCTION BOX TERMINAL
- MCCB - MAGNETIC CONTACTOR CIRCUIT
- SHFCB - SPACE HEATER FRONT CIRCUIT
- SHRCB - SPACE HEATER REAR CIRCUIT
- S/N - SOLID NEUTRAL

## NOTES:

- 1. UNLESS OTHERWISE NOTED USE #12 AWG
- 2. Δ-USE #4 AWG SIS GRAY WIRE.

## KEY



| ITEM NO.                                            | PART OR IDENTIFYING NO. | NOMENCLATURE OR DESCRIPTION | PARTS LIST |
|-----------------------------------------------------|-------------------------|-----------------------------|------------|
| 989-DF                                              |                         |                             |            |
| DUEL FUEL 1500 KW COMBUSTION OF DIESEL POWER PLANTS |                         |                             |            |
| SATISFACTORY TO:                                    |                         |                             |            |
| WHITE CHILDERS                                      |                         |                             |            |
| HONAH HELGESON, INC. 1958                           |                         |                             |            |





H

## G

**F**

E

D

C

B

A

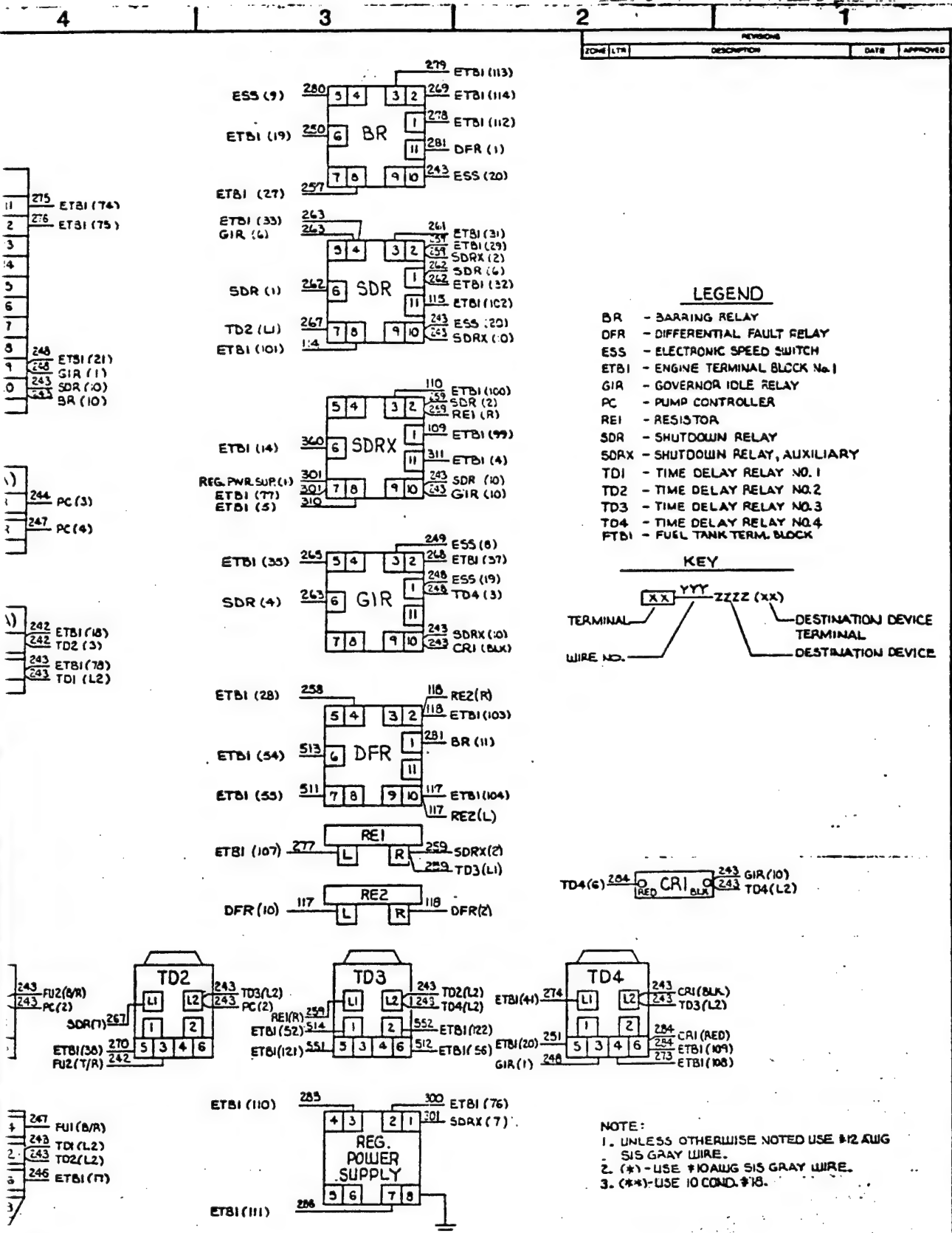
## ET81

| ACLO PUMP SUIT (L)         | 302 | 302 | WTB3 (3)                  |
|----------------------------|-----|-----|---------------------------|
| ACLO PUMP SUIT (L)         | 303 | 303 | CCCP                      |
| ACLO PUMP SUIT (L)         | 304 | 304 | WTB3 (4)                  |
| SDRX (11)                  | 311 | 311 | WTB3 (5)                  |
| SDRX (8)                   | 310 | 310 | ENG. PREHEAT SUIT (TL)    |
| WTB3 (6)                   | 321 | 321 | THERMOSTAT                |
| ENG. PREHEAT SUIT (BL)     | 320 | 320 | THERMOSTAT                |
| AIR COMP MODE SUIT (TL)    | 330 | 330 | WTB3 (8)                  |
| AIR COMP MODE SUIT (BL)    | 331 | 331 | ACC                       |
| FUEL SOLVING VALVE         | 341 | 341 | ACC                       |
| FUEL TRANS. SEL. SUIT (L)  | 350 | 350 | WTB3 (9)                  |
| FUEL TRANS. SEL. SUIT (L)  | 351 | 351 | WTB3 (10)                 |
| FUEL TRANS. SEL. SUIT (L)  | 350 | 350 | WTB3 (12)                 |
| FUEL TRANS. SEL. SUIT (BL) | 351 | 351 | FTB3 (1)                  |
| SDRX (6)                   | 360 | 360 | FTB3 (4)                  |
| EXT. FAN SUIT (TL)         | 370 | 370 | WTB3 (14)                 |
| ACLO PUMP SUIT (L)         | 380 | 380 | WTB3 (15)                 |
| AC (5)                     | 390 | 390 | D.C. LUBE OIL PUMP MTR.   |
| AC (6)                     | 400 | 400 | D.C. LUBE OIL PUMP MTR.   |
| ACLO PUMP SUIT (L)         | 410 | 410 | CTL. POWER SUIT (TR DECK) |
| FUZ (TR)                   | 420 | 420 | LSOP                      |
| BR (6)                     | 430 | 430 | PRELUDE ON LT. (L)        |
| ENG. START P/B (BL DECK)   | 440 | 440 | CTL. POWER SUIT (TL DECK) |
| TD4 (5)                    | 450 | 450 | LSOP                      |
| ESS (19)                   | 460 | 460 | START SOL.                |
| ENG. START P/B (TR DECK)   | 470 | 470 | TDI (LI)                  |
| ENG. START P/B (TL DECK)   | 480 | 480 | PLUG B-PIN 15             |
| ENG. START P/B (BL DECK)   | 490 | 490 | LOPS                      |
| ENG. START P/B (TL DECK)   | 500 | 500 | LOPS                      |
| TD1 (3)                    | 510 | 510 | OTL                       |
| TD1 (5)                    | 520 | 520 | OTL                       |
| BR (8)                     | 530 | 530 | HJWTS                     |
| DFR (4)                    | 540 | 540 | HJWTS                     |
| SDR (2)                    | 550 | 550 | GOV. PIN I **             |
| ENG. STOP P/B (TL)         | 560 | 560 | PLUG B-PIN 16             |
| ENG. STOP P/B (BL)         | 570 | 570 | SDR (3)                   |
| SDR (11)                   | 580 | 580 | GOV. PIN C **             |
| GCS (B/R)                  | 590 | 590 | PLUG B-PIN 17             |
| SDR (4)                    | 600 | 600 | PLUG B-PIN 19             |
| GCS (TL)                   | 610 | 610 | PLUG B-PIN 18             |
| GCS (BL)                   | 620 | 620 | LOT                       |
| GIR (5)                    | 630 | 630 | GOV. PIN G **             |
| GIR (2)                    | 640 | 640 | LOT                       |
| TD2 (5)                    | 650 | 650 | GOV. PIN E **             |
| PC (1)                     | 660 | 660 | GOV. PIN D **             |
| ACLO PUMP SUIT (BL/R)      | 670 | 670 | CCP                       |
| TD4 (LI)                   | 680 | 680 | CCCP                      |
| PRELUDE P/B (TL)           | 690 | 690 | CCP                       |
| LAPA                       | 700 | 700 | CCCP                      |
| LAPA                       | 710 | 710 | PLUG H-PIN 17             |
| FTBI (5)                   | 720 | 720 | PLUG H-PIN 8              |
| OTL                        | 730 | 730 | PLUG H-PIN 16             |
| OTL                        | 740 | 740 | PLUG H-PIN 1              |
| FTBI (6)                   | 750 | 750 | PLUG H-PIN 2              |
| FTBI (7)                   | 760 | 760 | PLUG H-PIN 15             |
| FTBI (8)                   | 770 | 770 | PLUG H-PIN 9              |
| HOTA                       | 780 | 780 | PLUG H-PIN 14             |
| HJWTA                      | 790 | 790 | PLUG H-PIN 3              |
| HJWTA                      | 800 | 800 | PLUG H-PIN 7              |
| LOPA                       | 810 | 810 | TD3 (1)                   |
| LOPA                       | 820 | 820 | PLUG H-PIN 4              |
| MTB3 (25)                  | 830 | 830 | PLUG H-PIN 12             |
| DFR (6)                    | 840 | 840 | PLUG H-PIN 8              |
| DFR (7)                    | 850 | 850 | TD3 (6)                   |
| MTB3 (26)                  | 860 | 860 | PLUG H-PIN 18             |
| ANNUAL CELL No.1 (1)       | 870 | 870 | PLUG H-PIN 19             |
| ANNUAL CELL No.1 (2)       | 880 | 880 | PLUG H-PIN 20             |
| ANNUAL CELL No.1 (3)       | 890 | 890 | PLUG H-PIN 21             |
| ANNUAL CELL No.2 (1)       | 900 | 900 |                           |

## ETBI

|                           |      |      |                         |                        |
|---------------------------|------|------|-------------------------|------------------------|
| ANNUAL CELL No.2 (2)      | 519  | 519  | PLUG H - PIN 22         |                        |
| ANNUAL CELL No.2 (4)      | 520  | 520  | PLUG H - PIN 23         |                        |
| ANNUAL CELL No.3 (1)      | 521  | 521  | PLUG H - PIN 24         |                        |
| ANNUAL CELL No.3 (2)      | 522  | 522  | PLUG H - PIN 25         |                        |
| ANNUAL CELL No.3 (4)      | 523  | 523  | PLUG H - PIN 26         |                        |
| ANNUAL P/B (1)            | 524  | 524  | PLUG H - PIN 28         | ETBI (1)               |
| ANNUAL P/B (3)            | 525  | 525  | PLUG H - PIN 29         |                        |
| ANNUAL P/B (4)            | 526  | 526  | PLUG H - PIN 30         | ETBI (1)               |
| ANNUAL P/B (6)            | 527  | 527  | PLUG H - PIN 31         | GIR (1)                |
| ANNUAL P/B (5)            | 528  | 528  | PLUG H - PIN 32         | BR (1)                 |
| ANNUAL CELL No.1 (3)      | 529  | 529  | PLUG H - PIN 27         |                        |
| ETB2 (1)                  | 534  | 534  | PLUG H - PIN 10         |                        |
| ETB2 (2)                  | 535  | 535  | PLUG H - PIN 11         | GS312/J3-12            |
| ETB3 (11)                 | 536  | 536  | PLUG H - PIN 11         |                        |
| TACH (1)                  | 537  | 537  | MAG PICKUP (B)          | *3 TUL                 |
| TACH (2)                  | 538  | 538  | MAG PICKUP (A)          | SHLD. PR.              |
| REG. FUEL SUPPLY (2)      | 539  | 539  | FUEL SOL. VALVE         |                        |
| FUEL TRANS. LT. (2)       | 540  | 540  | MTB3 (2)                |                        |
| SOX (7)                   | 541  | 541  | MTB3 (1)                | * ETBI (1)             |
| ACLO. PUMP SW. (B/A)      | 542  | 542  | START SOL.              | FU2 (1)                |
| ETBI (74)                 | 543  | 543  | GOV. PLUG F *A          | * ETBI (1)             |
| ETBI (70)                 | 544  | 544  | GOV. PLUG J *A          | FU2 (1)                |
| ETBI (115)                | 545  | 545  | FRELUDE D.C. SOL.       |                        |
| * FUI (T/L)               | 546  | 546  | MTB3 (19) *             |                        |
| * FUI (B/L)               | 547  | 547  | MTB3 (20) *             |                        |
| ENG. PREHEAT LT. (L)      | 548  | 548  | MTB3 (7)                |                        |
| 2 COND. (JWRTD) (RED L)   | 549  | 549  | PLUG A - PIN A          |                        |
| SHLD. (JWRTD) (RED R)     | 550  | 550  | PLUG A - PIN B          | 2 COND. SHLD.          |
| SHIELD-WIRE 541 #542      | 551  | 551  | SHIELD-WIRE 275 #276    | *16 TUL SHLD. PAIR     |
| ETBI (88)                 | 552  | 552  | SHIELD-WIRE 541 #542    |                        |
| 2 COND. (JWRTD) (WHITE R) | 553  | 553  | PLUG A - PIN D          | 2 COND. SHLD.          |
| SHLD. (JWRTD) (WHITE L)   | 554  | 554  | SHIELD-WIRE 543 #544    |                        |
| SHIELD-WIRE 543 #544      | 555  | 555  | ETBI (91)               |                        |
| ETBI (85)                 | 556  | 556  | PLUG A - PIN G          | 2 COND. SHLD.          |
| 2 COND. (LORTD) (RED L)   | 557  | 557  | PLUG A - PIN H          | SHLD.                  |
| SHLD. (LORTD) (RED R)     | 558  | 558  | SHIELD-WIRE 545 #546    |                        |
| SHIELD-WIRE 545 #546      | 559  | 559  | ETBI (38)               | *16 TUL SHLD. PAIR     |
| ETBI (94)                 | 560  | 560  | PLUG A - PIN K          | 2 COND. SHLD.          |
| 2 COND. (LORTD) (WHITE R) | 561  | 561  | PLUG A - PIN L          | SHLD.                  |
| SHLD. (LORTD) (WHITE L)   | 562  | 562  | SHIELD-WIRE 547 #548    |                        |
| SHIELD-WIRE 547 #548      | 563  | 563  | ETBI (97)               |                        |
| ETBI (91)                 | 564  | 564  | PLUG A - PIN N          | *16 TUL SHLD. PAIR     |
| LQ. PRESS. TRANS. (D)     | 565  | 565  | PLUG A - PIN P          |                        |
| LQ. PRESS. TRANS. (C)     | 566  | 566  | SHIELD-WIRE 559 #560    |                        |
| SHIELD-WIRE 559 #560      | 567  | 567  | ETBI (94)               |                        |
| FTBI (2)                  | 568  | 568  | MTB3 (13)               |                        |
| FTBI (3)                  | 569  | 569  | PLUG B - PIN 20         |                        |
| SOX (1)                   | 570  | 570  | PLUG B - PIN 21         |                        |
| SOX (3)                   | 571  | 571  | PLUG B - PIN 24         |                        |
| SOX (8)                   | 572  | 572  | PLUG B - PIN 25         | ETBI (1)               |
| SOX (11)                  | 573  | 573  | PLUG B - PIN 22         |                        |
| DFR (2)                   | 574  | 574  | PLUG B - PIN 23         | ETBI (1)               |
| DFR (10)                  | 575  | 575  | PLUG B - PIN 3          | ETBI (1)               |
| ESS (5)                   | 576  | 576  | PLUG B - PIN 4          |                        |
| ESS (7)                   | 577  | 577  | RTM (+)                 |                        |
| REI (L)                   | 578  | 578  | RTM (+)                 |                        |
| CTL. PWR. SW. (T/L) (C2)  | 579  | 579  | TD (+)                  |                        |
| TO4 (6)                   | 584  | 584  | PRELUDE D.C. SOL. VALVE | FUI (T/L)              |
| REG. POWER SUPPLY (3)     | 585  | 585  | L.Q.P. TRANSDUCER (A)   | ETBI (3)               |
| REG. POWER SUPPLY (7)     | 586  | 586  | L.Q.P. TRANSDUCER (D)   | *16 TUL SHLD. PR.      |
| BAR (1)                   | 587  | 587  | BAR RECEPT. (B)         | ETBI (1)               |
| LOCAL BAR P/B (T/L)       | 588  | 588  | BAR AIR SOL.            |                        |
| BAR (3)                   | 589  | 589  | AUTO BAR SW. (T/L)      |                        |
| BAR (2)                   | 590  | 590  | RTM (-)                 |                        |
| ETBI (79)                 | 591  | 591  |                         | GS340C/ER-10           |
| AUTO AIR BAR SOL.         | 592  | 592  |                         |                        |
| MTB3 (31)                 | 1001 | 1001 | PLUG B, PIN 26          |                        |
| MTB3 (32)                 | 1002 | 1002 | PLUG B, PIN 37          |                        |
| MTB3 (33)                 | 1003 | 1003 | PLUG B, PIN 38          | SPARES                 |
| MTB3 (34)                 | 1004 | 1004 | PLUG B, PIN 39          |                        |
| TD3 (5)                   | 551  | 551  | PLUG H, PIN 13          |                        |
| TD3 (2)                   | 552  | 552  | PLUG H, PIN 5           |                        |
|                           | 123  |      |                         | GS316/GAS DETECT LIGHT |
|                           | 124  |      |                         | GS316/J-29             |
|                           | 125  |      |                         | GS339/LDS-C2           |
|                           |      |      |                         | GS339A/T-39            |





| REV | FROM NO. | PART OR IDENTIFYING NO. | NOMENCLATURE OR DESCRIPTION | MATERIAL SPECIFICATION | ITEM NO. |
|-----|----------|-------------------------|-----------------------------|------------------------|----------|
| 1   |          |                         |                             |                        |          |
| 2   |          |                         |                             |                        |          |
| 3   |          |                         |                             |                        |          |
| 4   |          |                         |                             |                        |          |

| 990-DF                                            |     | OVERHAUL 1500 KW DIESEL POWER PLANTS CONNECTION DIAGRAM, ENGINE CONTROL PANEL |                  |
|---------------------------------------------------|-----|-------------------------------------------------------------------------------|------------------|
| PREPARED BY                                       | U-X | DATE                                                                          | 1992-7-1         |
| CHECKED BY                                        |     | DATE                                                                          |                  |
| APPROVED BY                                       |     | DATE                                                                          |                  |
| DUEL FUEL 1500 KW COMBOSOL OF DIESEL POWER PLANTS |     | SIZE                                                                          | F 80091          |
| SATISFACTORY TO: WIRE CHIEFS                      |     | SCALE                                                                         | NONE             |
| NORMAN HELGSON DEC 1998                           |     | DRWING NO.                                                                    | N47408-89-C-2011 |
|                                                   |     | SHEET                                                                         | 111 OF           |

H

G

F

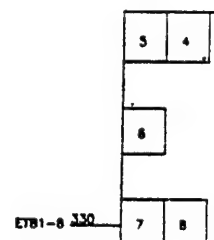
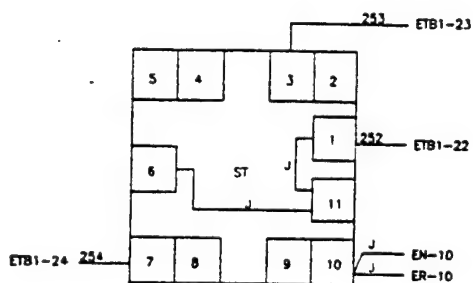
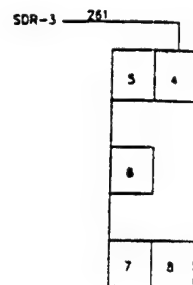
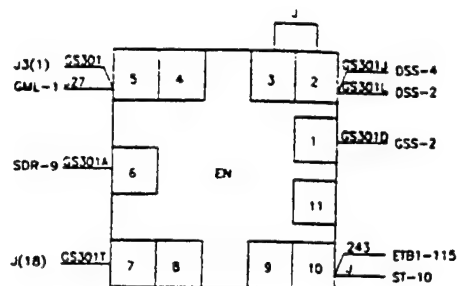
E

D

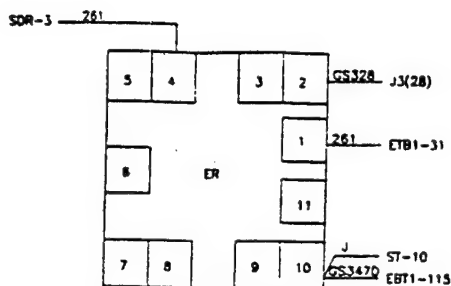
C

B

A

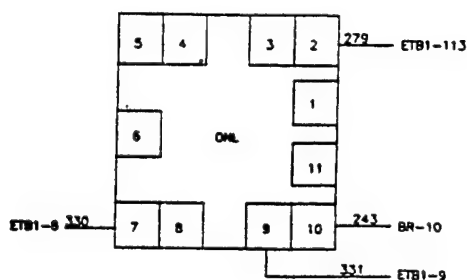


MOUNTED ON BACK WALL OF ECP



# LEGEND

EN - GAS SYSTEM ENABLE  
ER - ENGINE RUN RELAY  
OHL - AIR COMPRESSOR RUN  
ST - START RELAY



ED ON BACK WALL OF ECP

| QUANTITY FOR EACH ASSEMBLY                |            | ITEM NO.               | PART NO. | DESCRIPTION |
|-------------------------------------------|------------|------------------------|----------|-------------|
| VALUES SHOWN SHOULD BE IN FEET AND INCHES |            | PARTS LIST             |          |             |
| TOLERANCES:                               |            | DEPARTMENT OF THE NAVY |          |             |
| J. DECIMALS                               |            | NAVAL FACILITIES       |          |             |
| J. DECIMALS                               |            | PORT HUT               |          |             |
| J. DECIMALS                               |            | DUEL                   |          |             |
| J. DECIMALS                               |            | CONVERSION (           |          |             |
| FRACTIONS $\pm 1/16"$                     |            | ENGINE                 |          |             |
| ANGLES $\pm 0.5^\circ$                    |            | F 80091                |          |             |
| PART DASH NO.                             | NEXT ASSY. | APPROVED               | DATE     | SCALE NONE  |
|                                           |            | FOR COMMANDER, NAVFAC  |          |             |

B-53

IF IN DOUBT, ASK - DO NOT SCALE

2

128 JX(28)

ETB1-31

ST-10

470 EBT1-113

ETB1-113

BR-10

ETB1-9

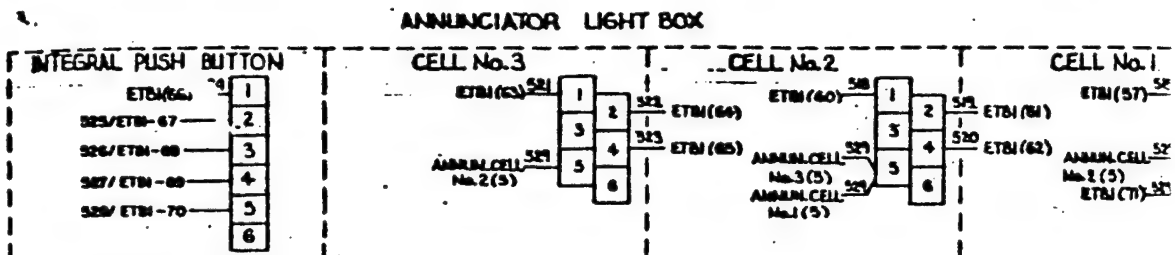
| ITEM NO. | DESCRIPTION | DATE | APPROVED |
|----------|-------------|------|----------|
|          |             |      |          |

LEGEND

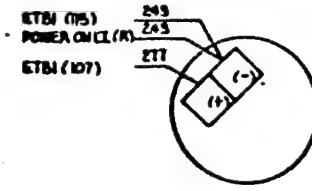
- EN - GAS SYSTEM ENABLE RELAY
- ER - ENGINE RUN RELAY
- OML - AIR COMPRESSOR RUN RELAY
- ST - START RELAY

|                                                                                                             |  |                                                                                                        |          |             |          |
|-------------------------------------------------------------------------------------------------------------|--|--------------------------------------------------------------------------------------------------------|----------|-------------|----------|
| QUANTITY FOR EACH ASSEMBLY                                                                                  |  | ITEM NO.                                                                                               | PART NO. | DESCRIPTION | MATERIAL |
| VALUES SPECIFIED SHOWN<br>DIMENSIONS ARE IN FEET AND/OR INCHES                                              |  | PARTS LIST                                                                                             |          |             |          |
| TOLERANCES:<br>X DECIMALS<br>XX DECIMALS<br>XXX DECIMALS<br>FRACTIONS $\pm 1/16"$<br>ANGLES $\pm 0.5^\circ$ |  | DUEL FUEL 1500 KW<br>CONVERSION OF DIESEL POWER PLANTS<br>CONNECTION DIAGRAM,<br>ENGINE CONTROL PANELS |          |             |          |
| PART NO.                                                                                                    |  | DATE                                                                                                   |          | SCALE       |          |
| NEXT ASSY.                                                                                                  |  | DATE                                                                                                   |          | SPEC        |          |
| FOR COMMANDER, NAVFAC                                                                                       |  | SCALE                                                                                                  |          | SHEET 1 OF  |          |

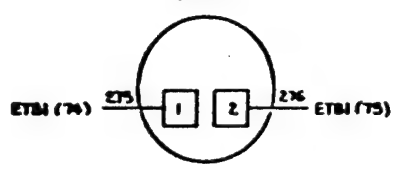
IN DOUBT, ASK - DO NOT SCALE



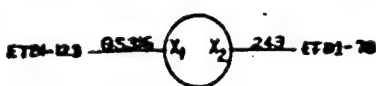
**ANNUNCIATING TIME METER (RTM)**



**TACH**



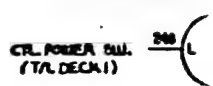
**GAS DETECTION ALARM**



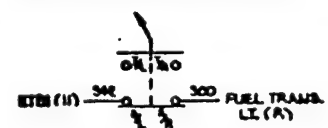
**FUEL TRANS. LIGHT**



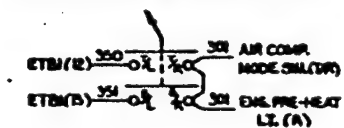
**CONTROL POWER**



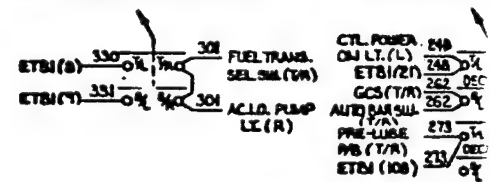
**FUEL TRANS. MODE SWITCH**



**FUEL TRANS. SELECTOR SW.**



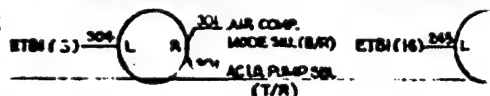
**AIR COMP. MODE SWITCH**



**ENGINE PRE-HEAT LIGHT**

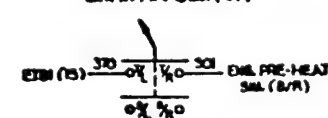


**AC LO. PUMP LIGHT**

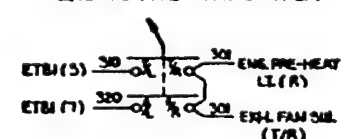


**DC LO. CIRC. F**

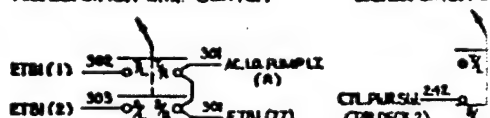
**EXH. FAN SWITCH**



**ENGINE PRE-HEAT SWITCH**

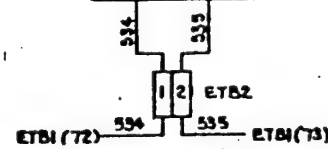
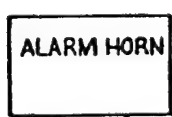


**AC LO. CIRC. PUMP SWITCH**

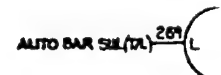


**DC LO. CIRC. PL**

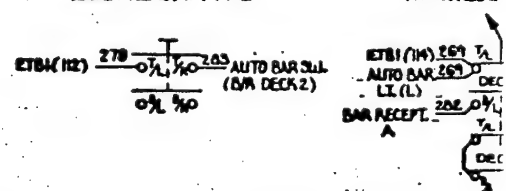
**CTL. PUMP SW. (T/A DECK 2)**



**AUTO. BAR**



**LOCAL BAR P/B**



**AUTO B. RUN. LOC.**



Diagram illustrating a two-cell system (CELL No. 1 and CELL No. 2) with ETB (Error Tolerance Block) components and associated data flow.

**CELL No. 1:**

- ETB(57) is connected to ETB(61) and ETB(62).
- ETB(61) is connected to ETB(62).
- ETB(62) is connected to ETB(71).
- ETB(71) is connected to ETB(57).
- ETB(57) is connected to ETB(61) and ETB(62).
- ETB(61) is connected to ETB(62).
- ETB(62) is connected to ETB(71).
- ETB(71) is connected to ETB(57).

**CELL No. 2:**

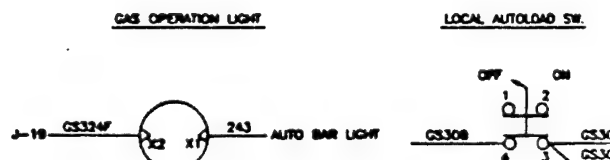
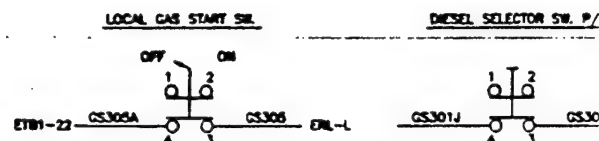
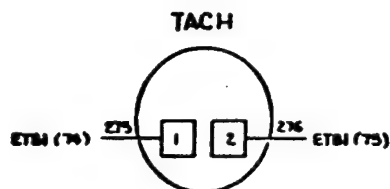
- ETB(64) is connected to ETB(65) and ETB(66).
- ETB(65) is connected to ETB(66).
- ETB(66) is connected to ETB(64).

**Data Flow:**

- ETB(64) is connected to ETB(65) and ETB(66).
- ETB(65) is connected to ETB(66).
- ETB(66) is connected to ETB(64).
- ETB(64) is connected to ETB(65) and ETB(66).
- ETB(65) is connected to ETB(66).
- ETB(66) is connected to ETB(64).

**Annotations:**

- CELL No. 1: ETB(57), ETB(61), ETB(62), ETB(71).
- CELL No. 2: ETB(64), ETB(65), ETB(66).
- CELL No. 1: ETB(57), ETB(61), ETB(62), ETB(71).
- CELL No. 2: ETB(64), ETB(65), ETB(66).



1 (75)  
- TRANS  
242 (8/75)



ENG. START P/B  
(T/A DECK 1)

252 L R 243  
243

POWER ON LT. (R)  
PRE-LUBE LT. (A)

CP-3 953044

The schematic diagram illustrates the fuel system components and their interconnections. On the left, the 'FUEL TANK' is shown with two output lines: 'FUEL TANK (F)' and 'FUEL TANK (F)'. These lines connect to the 'FUEL TRANS. SEL. SOL. (FVS)' unit. The 'FVS' unit has two output lines: 'FVS (F)' and 'FVS (F)'. These lines connect to the 'FUEL PUMP (FPL)' and 'FUEL PUMP (FPL2)' units. The 'FPL' unit has two output lines: 'FPL (F)' and 'FPL (F)'. These lines connect to the 'FUEL PUMP (FPL2)' unit. The 'FPL2' unit has two output lines: 'FPL2 (F)' and 'FPL2 (F)'. These lines connect to the 'FUEL TRANS. SEL. SOL. (FVS)' unit. The 'FVS' unit also has a 'FVS (F)' line that connects to the 'FUEL TANK (F)'.

CTL POWER  
CW LT.(L)  
ETB1(2N)  
GCS(T/M)  
AUTO BARSILL  
(T/M)  
PPE-LUBIE  
PMB(T/A)  
ETB1(108)

249  
248  
262  
262  
273  
273

248  
DECK 1  
248  
DECK 2  
248  
D.C. LO PUMP  
SdL (B/L)

ETB1(108)

[illegible]

ETB(16) —<sup>246</sup>— L — R —<sup>246</sup>— ETB(17)

ETIM (30) <sup>251</sup> L R <sup>249</sup> ENG. READY LZ (R)  
<sup>243</sup> AUTO BAR LZ (R)

ET81 (41)  $\frac{274}{\circ 1} \frac{273}{\circ 2}$  CTL. POWER SUPPLY (7A DECK 2)

ETBI (33) 263 264

ETBI (34) 264 262

CTL POWER SBL (MIL DECK 1)

ETBI (33)

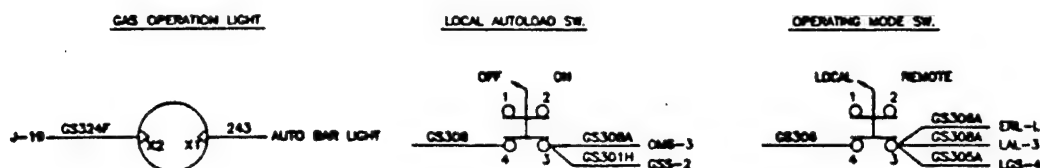
AUTO BAR SHL (TL)  $\frac{269}{L}$   $\frac{243}{R}$  PRE-LUBE LT. (R)

KTBA (112) 278  $\frac{0}{0}$   $\frac{1}{1}$   $\frac{0}{0}$  263 AUTO BAR SH.  
(C/M DECK 2)

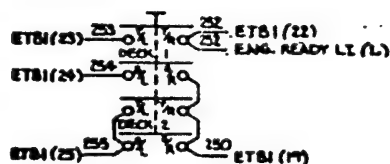
TERMINAL

WIRE NO.

|          |          |                                                       |  |                                          |          |
|----------|----------|-------------------------------------------------------|--|------------------------------------------|----------|
|          |          | QUANTITY FOR EACH ASSEMBLY                            |  | ITEM NO.                                 | PART NO. |
|          |          | VALUES SHOWN SHOULD BE RECHECKED AND IF NOT RECHECKED |  | FIELD NO.                                |          |
|          |          | TOLERANCES                                            |  | DEC. IN.                                 | 99       |
|          |          | IN DECIMALS                                           |  | DEC. XX                                  | OR       |
|          |          | OR DECIMALS                                           |  | CH. XX                                   |          |
|          |          | OR DECIMALS                                           |  | BRANCH HEAD SLACK                        |          |
|          |          | FRACTIONS                                             |  | BY CH.                                   |          |
|          |          | ASLES                                                 |  | RECHECKED BY MR. J. H. HANMAN - HELGESON |          |
|          |          | ± 1/16"                                               |  | APPROVED                                 |          |
|          |          | ± 0.5                                                 |  | COMMANDED OFFICER                        |          |
|          |          |                                                       |  | APPROVED                                 |          |
| PART NO. | NEW REV. | FOR COMMENTS, NEW                                     |  |                                          |          |



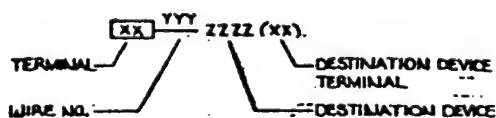
ENG. START P/B (T/A DECK 1) 252 L   R 243 POWER ON LT. (R)  
243 PRE-LUBE LT. (R)



ETM (30) <sup>251</sup> L R <sup>243</sup> <sub>244</sub> ENG. READY LZ (R)  
AUTO BAR LZ (R)

ETBI (41) CTL POWER SW (T/A DECK 2) ETBI (33) CTL POWER SW (T/A DECK 1)  
ETBI (34) CTL POWER SW (T/A DECK 1)

NOTE  
UNLESS OTHERWISE NOTED #12AUG SIS GRAY WIRE.

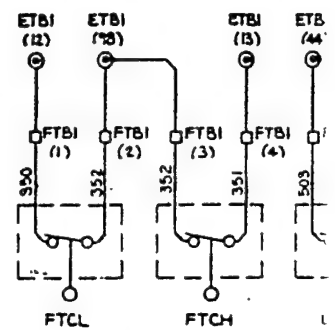
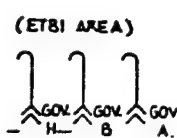
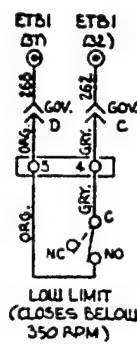
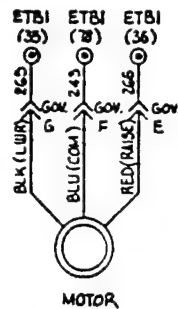
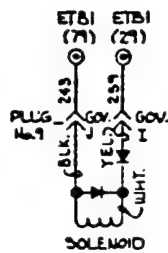


**IF IN DOUBT, ASK - DO NOT SCALE**

100-101

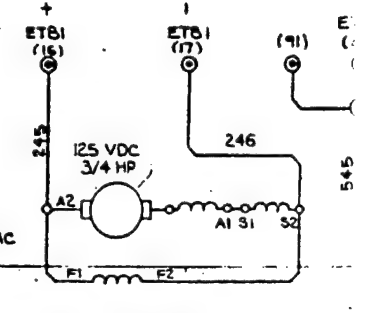
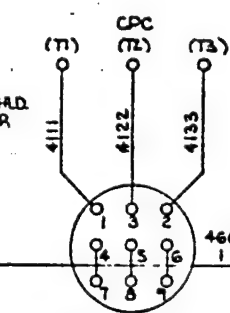
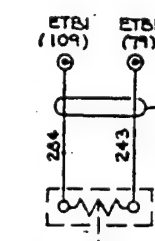
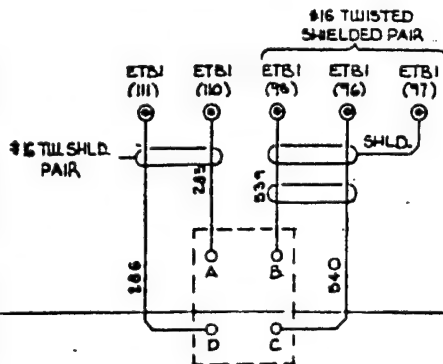
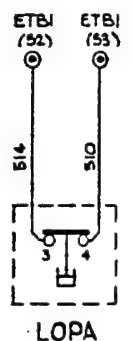
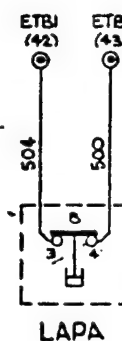
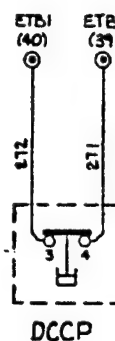
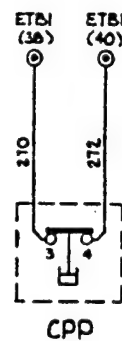
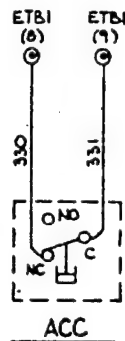
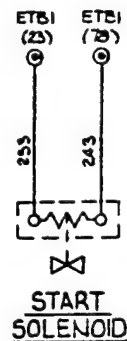
3

|                                                               |  |                                                       |  |                                             |  |                                                                                                       |  |            |  |
|---------------------------------------------------------------|--|-------------------------------------------------------|--|---------------------------------------------|--|-------------------------------------------------------------------------------------------------------|--|------------|--|
|                                                               |  | ITEM NO.                                              |  | PART NO.                                    |  | DESCRIPTION                                                                                           |  | ISSUED     |  |
| QUANTITY FOR EACH ASSEMBLY                                    |  | PART NO.                                              |  | PARTS LIST                                  |  |                                                                                                       |  |            |  |
| VALUES SHOWN (STANDARD)<br>STANDARD AND 1/2 INCH ANGLES SHOWN |  | PART NO.                                              |  | DEPARTMENT OF THE NAVY                      |  | 1954, FACILITIES ENGINEERING SERVICE CENTER                                                           |  |            |  |
|                                                               |  | 991- DF                                               |  | NAVAL FACILITIES ENGINEERING SERVICE CENTER |  | PUEBLO BLVD., CALIFORNIA 92045                                                                        |  |            |  |
| TOLERANCES<br>.12 DECIMALS                                    |  | END XX                                                |  | END 7 DELAWARE                              |  |                                                                                                       |  |            |  |
| JOB DECIMALS                                                  |  | END XX                                                |  |                                             |  |                                                                                                       |  |            |  |
| JOB DECIMALS                                                  |  | BRANCH HEAD (LARGE)                                   |  |                                             |  |                                                                                                       |  |            |  |
| FUNCTIONS                                                     |  | END XX                                                |  |                                             |  |                                                                                                       |  |            |  |
| ANGLES                                                        |  | REWORKED IN 1954-1955<br>1 NORMAN, MISSOURI, DEC 1954 |  |                                             |  | DUEL FUEL 1500 KW<br>CONVERSION OF DIESEL POWER PLANTS<br>CONNECTION DIAGRAM,<br>ENGINE CONTROL PANEL |  |            |  |
| 21/16                                                         |  | APPROVED                                              |  | DATE                                        |  | DATE REVISION NO.                                                                                     |  |            |  |
| 20.5                                                          |  | COMMANDED OFFICER                                     |  | F 80091                                     |  | CHANGE CENTER NO.                                                                                     |  |            |  |
|                                                               |  | APPROVED                                              |  | DATE                                        |  | SCALE NONE                                                                                            |  | SHEET 1 OF |  |
|                                                               |  | FOR COMMANDER, SEA/AC                                 |  |                                             |  |                                                                                                       |  |            |  |



GOVERNOR

FUEL LEVEL SWITCH

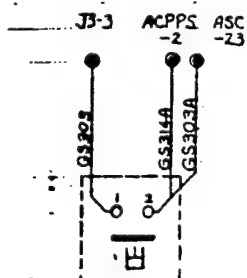


LUBE OIL PRESSURE TRANSDUCER

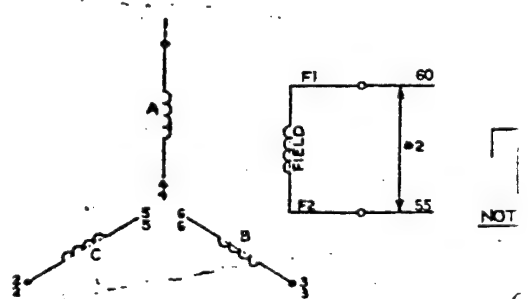
PRELUBE SOLENOID VALVE

AC LUBE OIL CIRCULATING PUMP MOTOR

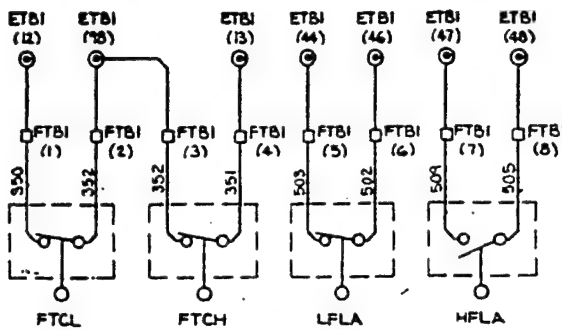
DC LUBE OIL CIRCULATING PUMP MOTOR



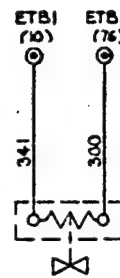
FOPS



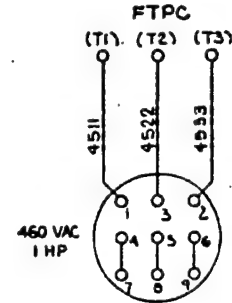
GENERATOR



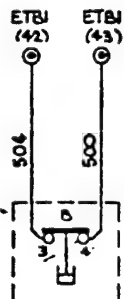
FUEL LEVEL SWITCH ASSEMBLY



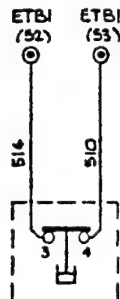
FUEL SOLENOID VALVE



FUEL OIL TRANSFER PUMP MOTOR



LAPA



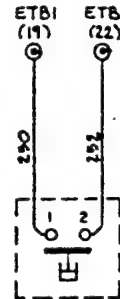
LOPA



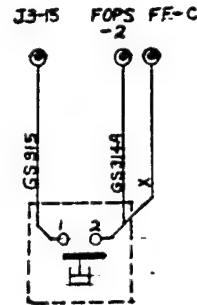
ACCP



LOPS



LSOP



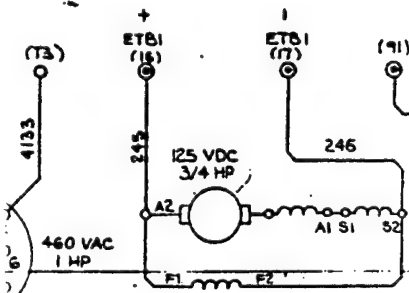
ACPPS

LEGEND

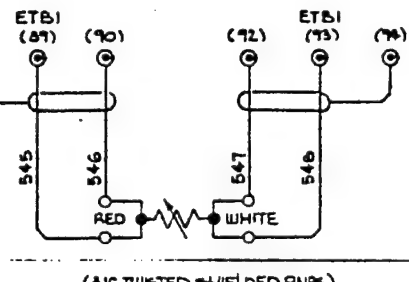
- ACPPS - AFTER COOL
- ACC - AIR COMPRESS
- ACCP - A.C. CIRCULAT
- CPP - CIRCULATING
- DCCP - D.C. CIRCULAT
- LAPA - LOW AIR PRES
- LOPA - LOW OIL PRES
- LOPS - LOW OIL PRES
- LORTO - LUBE OIL RES
- LSOP - LOW STAND
- OTL - OVERSPEED
- FTBI - FUEL TANK
- FOPS - FUEL OIL P

NOTE :

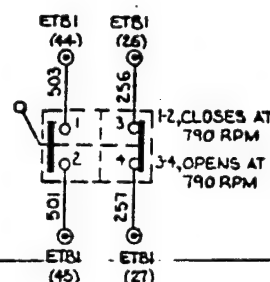
L UNLESS NOTED OTHER  
SIS GRAY WIRE.



OIL PUMP  
DC LUBE OIL CIRCULATING PUMP MOTOR.

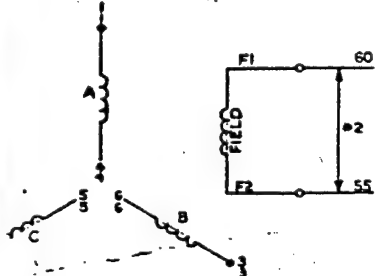


LORTO

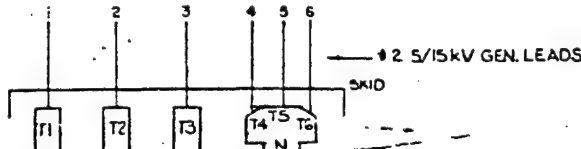


OTL

| OPERATING POINT: |       |      |
|------------------|-------|------|
| SWITCH           | CLOSE | OPEN |
| PRESSURE PSI     |       |      |
| ACC              | 200   | 24   |
| ACCP             | 20    | 3    |
| CPP              | 12    | 15   |
| DCCP             | 35    | 45   |
| LAPA             | 150   | 175  |
| LOPA             | 35    | 45   |
| LOPS             | 30    | 20   |
| LSOP             | 15    | 12   |
| ACPPS            | 40+   | 40   |
| FOPS             | 20+   | 20   |



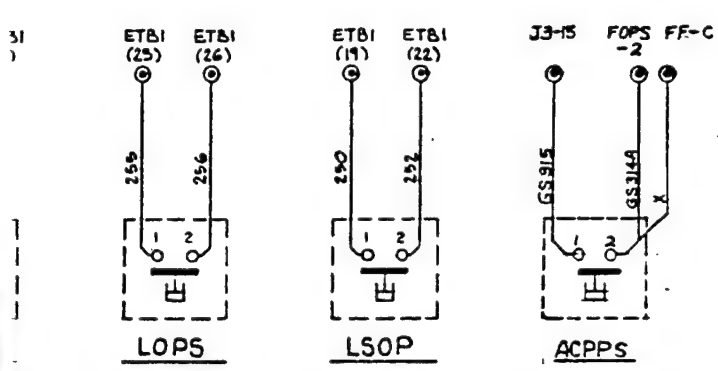
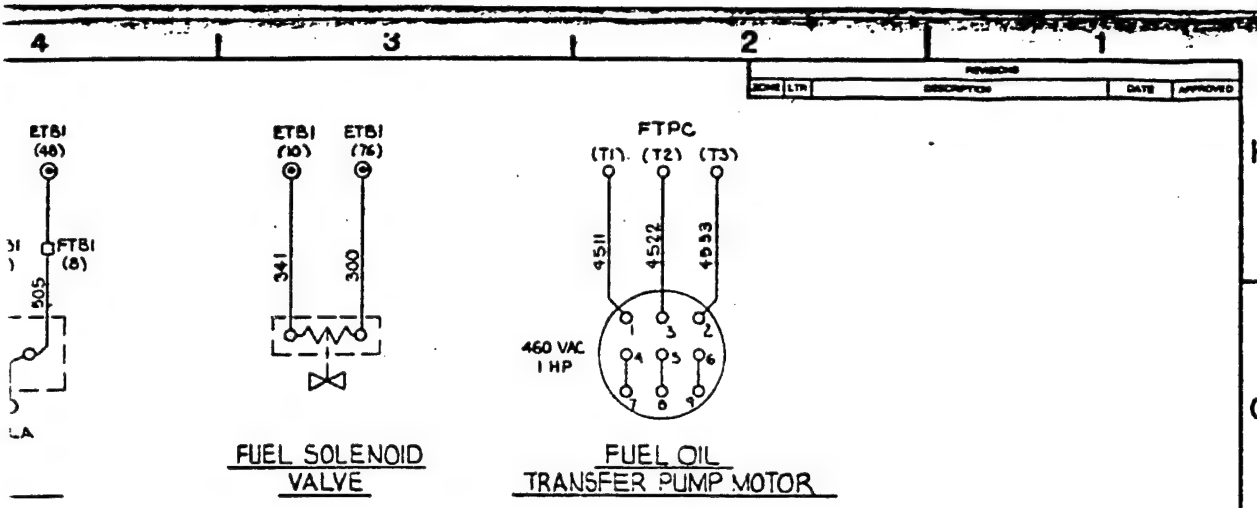
GENERATOR



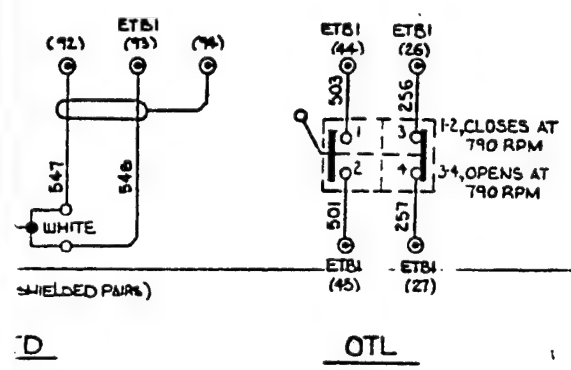
GEN.OUTPUT CONN. BOX

NOTE: AT EACH CONN. POINT, ONE CABLE GOES ABOVE BUS BAR, ONE GOES BELOW BUS BAR.

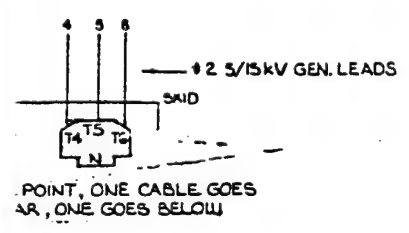
| DATE                                                 | FROM NO. | PART NO. | IDENTIFYING NO. | NOMENCLATURE OR DESCRIPTION |
|------------------------------------------------------|----------|----------|-----------------|-----------------------------|
| 1992-7-1                                             | 993-DF   | 1992-7-1 |                 |                             |
| PREPARED                                             | REVIEWED | DESIGNED | CHECKED         | APPROVED                    |
|                                                      |          |          |                 |                             |
| DUEL FUEL 1500 KW COMBINATION OF DIESEL POWER PLANTS |          |          |                 |                             |
| SIGNED BY                                            |          |          |                 |                             |
| SCALE                                                |          |          |                 |                             |
| F 800                                                |          |          |                 |                             |



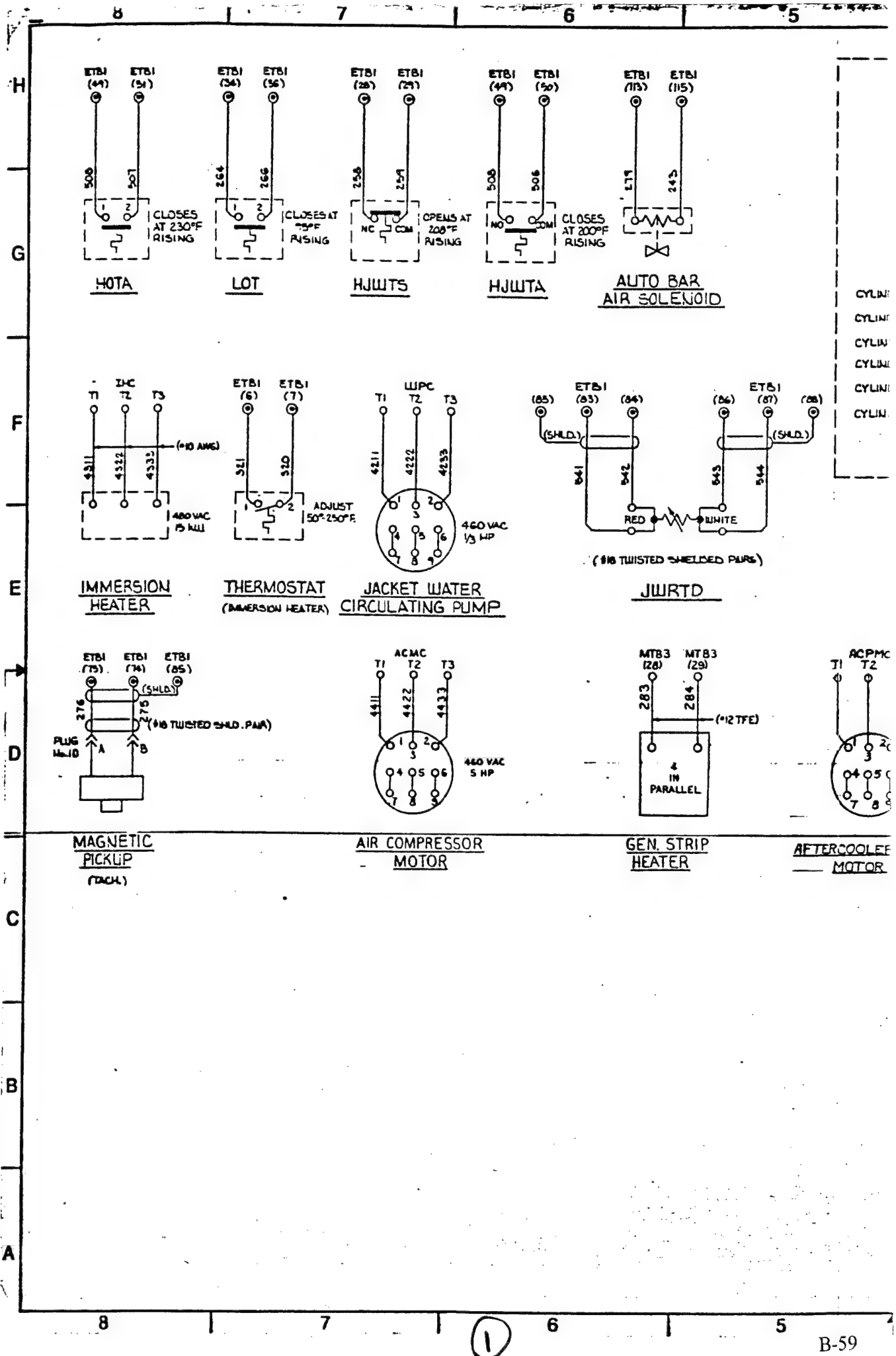
- LEGEND**
- ACPPS - AFTER COOLER PUMP PRESSURE SWITCH
  - ACC - AIR COMPRESSOR CONTROLLER
  - ACCP - A.C. CIRCULATING PUMP SWITCH
  - CPP - CIRCULATING PUMP PRESSURE SWITCH
  - DCCP - D.C. CIRCULATING PUMP SWITCH
  - LAPA - LOW AIR PRESSURE ALARM
  - LOPA - LOW OIL PRESSURE ALARM
  - LOPS - LOW OIL PRESSURE SHUTDOWN
  - LORTD - LUBE OIL RESISTANCE TEMP DETECTOR
  - LSOP - LOW STANDBY OIL PRESSURE
  - OTL - OVERSPEED TRIP LIMIT SWITCH
  - FTBI - FUEL TANK TERMINAL BLOCK
  - FOPS - FUEL OIL PRESSURE SWITCH

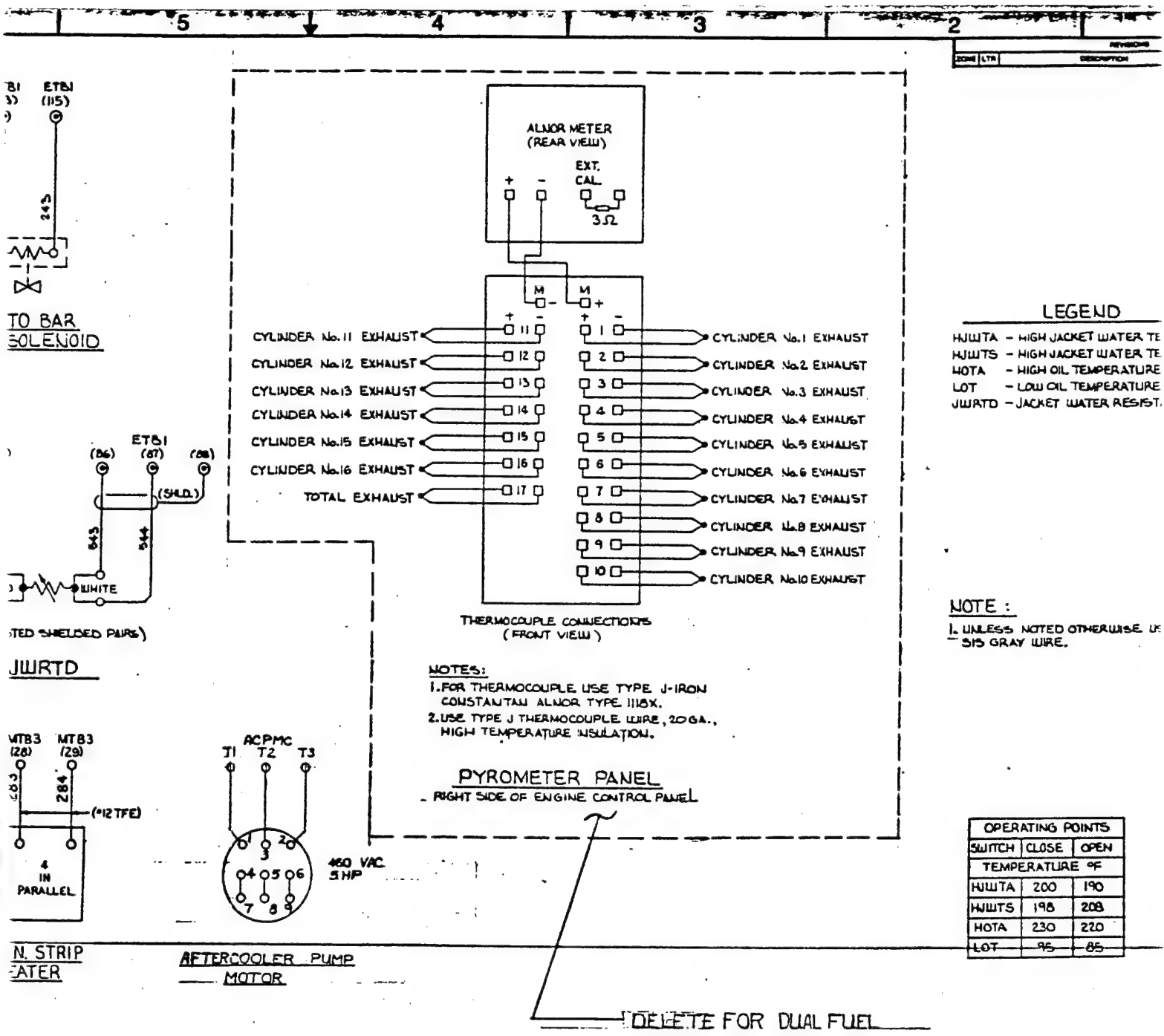


| OPERATING POINTS |       |      |
|------------------|-------|------|
| SWITCH           | CLOSE | OPEN |
| PRESSURE PSI     |       |      |
| ACC              | 200   | 240  |
| ACCP             | 20    | 30   |
| CPP              | 12    | 15   |
| DCCP             | 35    | 45   |
| LAPA             | 150   | 175  |
| LOPA             | 35    | 45   |
| LOPS             | 30    | 20   |
| LSOP             | 15    | 12   |
| ACPPS            | 40+   | 40+  |
| FOPS             | 20+   | 20+  |



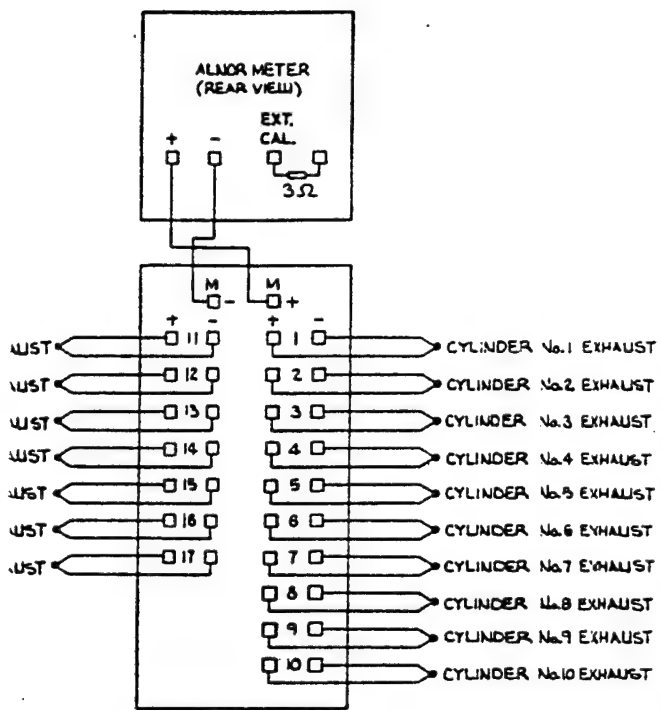
|                                                     |              |                                                                                 |                        |          |
|-----------------------------------------------------|--------------|---------------------------------------------------------------------------------|------------------------|----------|
| FORM NO.                                            | PART NO.     | DESCRIPTION                                                                     | MATERIAL SPECIFICATION | ITEM NO. |
| 993-DF                                              |              | OVERHAUL 1500 KW DIESEL POWER PLANTS CONNECTION DIAGRAM, ENGINE HOUSE EQUIPMENT |                        |          |
| PREPARED BY                                         | DESIGNED BY  | CHECKED BY                                                                      | APPROVED BY            | DATE     |
| W. H. CHILDS                                        | W. H. CHILDS | W. H. CHILDS                                                                    | W. H. CHILDS           | 1992-7-1 |
| DUEL FUEL 1500 KW COMMISSION OF DIESEL POWER PLANTS |              | F 80091                                                                         |                        |          |
| SHEET 114 OF 114                                    |              | N47408-89-C-2011                                                                |                        |          |





|                                   |          |                         |                             |                |
|-----------------------------------|----------|-------------------------|-----------------------------|----------------|
| QTY REQ                           | FROM NO. | PART OR IDENTIFYING NO. | NOMENCLATURE OR DESCRIPTION | MATERIAL SPEC. |
| PARTS LIST                        |          |                         |                             |                |
| MEDIA ORIGIN NO.                  |          |                         | DEPARTMENT OF THE NAVY      |                |
| 994-DF                            |          |                         | NAVAL ENERGY AND ENVR       |                |
| REVISED 10-61                     |          |                         | 1992-7-1                    |                |
| REVIEWED                          |          |                         | OVERHAUL                    |                |
| ENGINEER                          |          |                         | DIESEL PUMP                 |                |
| ENGINEER                          |          |                         | CONNECT ENGINE HO           |                |
| DATE                              |          |                         | DATE                        | DATE           |
| Satisfactory to                   |          |                         | DATE                        | DATE           |
| WIRE CHECKED                      |          |                         | DATE                        | DATE           |
| NORMAN HILLIS/SON, INC. 1998      |          |                         | DATE                        | DATE           |
| DUEL FUEL 1500 KW                 |          |                         | DATE                        | DATE           |
| CONVERSION OF DIESEL POWER PLANTS |          |                         | DATE                        | DATE           |
| F 80091                           |          |                         | DATE                        | DATE           |
| NONE                              |          |                         | DATE                        | DATE           |

ALNOR METER  
(REAR VIEW)



THERMOCOUPLE CONNECTIONS  
(FRONT VIEW)

- NOTES:
1. FOR THERMOCOUPLE USE TYPE J-IRON CONSTANTAN ALNOR TYPE 1110X.
  2. USE TYPE J THERMOCOUPLE WIRE, 20 GA., HIGH TEMPERATURE INSULATION.

PYROMETER PANEL

- RIGHT SIDE OF ENGINE CONTROL PANEL

LEGEND

- HJWTA - HIGH JACKET WATER TEMPERATURE ALARM  
HJWTS - HIGH JACKET WATER TEMPERATURE SHUTDOWN  
HOTA - HIGH OIL TEMPERATURE ALARM  
LOT - LOW OIL TEMPERATURE SWITCH  
JWATD - JACKET WATER RESISTANCE TEMP. DETECTOR

NOTE :

1. UNLESS NOTED OTHERWISE USE #12 AWG  
- 315 GRAY WIRE.

| OPERATING POINTS |       |      |
|------------------|-------|------|
| SWITCH           | CLOSE | OPEN |
| TEMPERATURE °F   |       |      |
| HJWTA            | 200   | 190  |
| HJWTS            | 198   | 208  |
| HOTA             | 230   | 220  |
| LOT              | 95    | 85   |

DELETE FOR DUAL FUEL

|                                                                                                                                                     |          |                         |                                                                                                                                                                         |                        |          |
|-----------------------------------------------------------------------------------------------------------------------------------------------------|----------|-------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------|----------|
| QTY/REQ                                                                                                                                             | FROM NO. | PART OR IDENTIFYING NO. | NOMENCLATURE OR DESCRIPTION                                                                                                                                             | MATERIAL/SPECIFICATION | ITEM NO. |
| PARTS LIST                                                                                                                                          |          |                         |                                                                                                                                                                         |                        |          |
| MEDIA DRAWING NO.<br><b>994-DF</b>                                                                                                                  |          |                         | DEPARTMENT OF THE NAVY<br>NAVAL FACILITIES ENGINEERING COMMAND<br>NAVAL ENERGY AND ENVIRONMENTAL SUPPORT ACTIVITY<br>1400 LYONS ST. PORT HUNTERS, CALIFORNIA 90340-1400 |                        |          |
| PREPARED BY: <b>U-4</b><br>CHECKED BY: <b>1992-7-1</b><br>REVIEWED BY: <b>1992-7-1</b><br>DESIGNED BY: <b>1992-7-1</b><br>DRAWN BY: <b>1992-7-1</b> |          |                         | OVERHAUL 1500 KW<br>DIESEL POWER PLANTS<br>CONNECTION DIAGRAM,<br>ENGINE HOUSE EQUIPMENT                                                                                |                        |          |
| DUAL FUEL 1500 KW<br>CONNECTION OF DIESEL POWER PLANTS<br>Satisfactory to: <b>1992-7-1</b><br>NAME: <b>CHILDS</b><br>POSITION: <b>ILLUSTRATOR</b>   |          |                         | APPROVED: <b>F</b> DATE: <b>80091</b><br>CASE NO. <b>80091</b><br>NAVJAC DRAWING NO. <b>N47408-89-C-2011</b><br>SHEET 115 OF 115                                        |                        |          |



## **Appendix C**

### **MAINTENANCE BULLETINS AND INSTRUCTIONS**

#### **CONTENTS**

|                                                                                                                 | <b>Page</b> |
|-----------------------------------------------------------------------------------------------------------------|-------------|
| Special Tools .....                                                                                             | C-2         |
| Injector Settings and Adjustments for ECI-Converted Dual Fuel<br>Engines in Stationary Power Applications ..... | C-3         |
| Injector Calibration for Dual Fuel-Converted Engines .....                                                      | C-6         |
| Recommended Spare Parts List.....                                                                               | C-8         |
| Troubleshooting - Stationary Power.....                                                                         | C-11        |



# Energy Conversions Inc.

Natural Gas power from EMD engines

Technical bulletin 05-001 2/ 7/96 Pg 1 of 1

**Subject : Special tools used on natural gas converted engine systems**

**File name: TBTOOL.DOC**

ECI has worked to keep the required special tools to a minimum. There are several tools that are required for proper servicing and operation of the converted engine. At the bottom is a short list of tools that are not supplied by ECI.

**Rack Measuring Tool** p/n 05-0130: This required tool is needed to properly set the level of diesel pilot fuel. Code named boomerang. This tool is not designed to come back if you throw it real hard. The boomerang has a detachable standard that is used to calibrate it. The standard is available separately if lost or misplaced. p/n 05-0132

**GIV port brush** p/n 05-0112: Not required, but useful. This bottle cleaning brush works well for cleaning out the oil and small debris that may be left in the hole where the Gas Inlet Valve fits into the cylinder head. If there is heavy buildup from a leaking seal washer this brush won't help. You will need a ream. ECI can supply a modified ream that will scrape clean the surface where the seal washer sets too. p/n 05-0113

**GIV removal and installation tools:** 1/4" drive - 7/32" hex driver, 6" long 1/4" wobble extension, 1/4" to 3/8" drive adapter and a torque wrench that can indicate torque at 22 Ft. Lbs. is needed for Gas Inlet Valve installation. Snap-On part numbers indicated in the table below.

|         |                                      |
|---------|--------------------------------------|
| GTMA7   | Hex wrench for GIV crab bolts        |
| GTMXW60 | Extension 1/4" wobble 6" long        |
| GTMA1   | 1/4" - 3/8" adapter                  |
| GSCO40  | Gas line crows foot 1 1/4" 1/2 drive |

**Pressure gauge:** 0-160 PSI hand held gauge with adapter fitting for quick connect/disconnect

**Adapter fitting:** for installation to relief valve, allowing measurement of compression or combustion pressure using standard Keim indicating gauge.

**Useful tools not normally supplied by ECI:**

A pump spray bottle for searching out pipe leaks using soapy water.

3/16 lead wire for taking Piston to head clearance (available from EMD)

Torque wrench, 3/8" drive 15-75 Ft. Lbs. (Snap On # QJFR275E)



# Energy Conversions Inc.

Natural Gas power from EMD engines

Technical bulletin 20-001 2/6/96 Pg.1 of 3

**Subject :** Injector settings and adjustments for ECI converted dual fuel engines in stationary power applications. Page 1 of 3

**File Name:** TBINJECT.DOC

Use the special ECI tool to measure the rack lengths. It is designed to better fit the tight areas of the injector rack and to measure the longer rack positions.

For initial setup of the racks after kit installation and any time that the engine governor is changed or if significant linkage service is performed start at step number 1. If a routine adjustment is to be performed or inspections are to be made start at step 5.

A simplified description of the steps taken to adjust pilot fuel is to first make an initial adjustment of injector rack to governor position. (injector to governor relationship). Next make an adjustment the pilot stop adjustment screw and third set the injector racks.

Standard settings for injectors are dependent on the part number of the injector applied to the converted engine. The 5229335 injector will operate well at a injector rack setting of 1.870" the 5229250

injector will operate better set at 1.830" Testing has shown that when Roots engine injectors are installed into Turbocharged engines they can provide a reduced pilot fuel consumption. However there are other variables that can affect the combustion of pilot fuel to the level that increased rack settings are required. Efficient air after-cooling and large load changes create a potential for misfire. To avoid misfire the pilot fuel must be increased. The rack setting value for turbocharged natural gas engines using injector part number 5229200 will vary depending on the type of air after cooling equipment used and the type of duty cycle that the engine is normally operated. Additionally due to manufacturing tolerances, rack adjustment should be done when the injector racks are at the pilot fuel level.

The table indicates expected rack settings for different operations

| Load swing           | After Cooling | Rack Setting |           |
|----------------------|---------------|--------------|-----------|
| Tool standard length |               | 1.870"       |           |
| Low to Medium        | Enhanced      | 1.830"       | Navy MUSE |
| Low to medium        | Extended      | 1.800        |           |
| High                 | Extended      | 1.780"       | Rig 801   |

The detailed procedure for proper injector setting is as follows.

1. Make certain that air pressure is available to the gas control system and turn the gas supply off.

2. Install a governor jack and adjust it to hold the governor and injector racks to the full fuel position. Pay attention to the possibility that one or more injectors links maybe to short and bottoming out on the injector. This would cause adjustment errors. Extend the adjustment of any cylinder if this is the case, insuring that the governor is free to go to its full fuel stop.

3. Set up the rack tool so it indicates zero with the 0.625" standard (the short end) On two of the cylinders, one on each bank (easiest if it is the first cylinder on the bank) adjust the racks to 0.625".

4. Remove the governor jack and set the fuel limit knob on the governor to the no fuel position.

5. Press the buttons on the gas system diagnostic screen, Alt + Page Down. This will put air pressure on the pilot stop ram. (If gas pressure over 25 psi is detected by the ECU it will not put air pressure on the system. It may be necessary to manually bleed off some of the gas pressure to allow the adjustment. This is conveniently done at the point where the gas pressure test point is located.)

6. Calibrate the rack tool to zero on the long side of the standard. (see notes on using the rack tool)

7. Measure the injector racks of the injectors that were set to 0.625" make adjustments as necessary to the pilot stop ram screw so that the injectors you previously set at the 0.625" setting are very near the tools setting with the standard. (You may find that the injectors are not equal. One rack may be longer than the proper setting and one may be shorter. In this case split the difference). Now you are done making adjustments to the pilot stop adjusting screw.

8. Set all of the injectors to the proper pilot fuel setting as indicated in the above tables. (including the two used for governor to injector relationship) Accuracy is critical to insure proper gas operation.

9. Return the fuel limit knob on the governor to the max fuel position

10. Press a button on the ECU screen to deactivate the pilot stop test.

11. Open the gas supply manual valve.

### **Notes on using the ECI rack measuring tool**

The ECI rack tool is used to measure the length of the diesel injector racks for the purpose of adjusting and setting the diesel injectors for proper dual fuel operation. It is designed to fit the tight areas of the injector rack area and to measure the long rack positions.

Prior to taking measurements the tools calibration should be checked. Hold the standard in place and set the dial to zero. You may find this a little difficult. By using your thumb you can move the tools lever and lessen the force from the spring on the standard. After you have made adjustments to the tool and rechecked them you are ready to measure the prepared engine injector racks.

The indicator on the rack measuring tool reads 1/2 of the actual rack deviation because of the lever to pivot ratio. The adjusted rack length change is twice the reading of the indicator scale (2:1 ratio). For an example, a rack adjustment of 0.020" would only indicate a 0.010" on the dial.

Careful attention should be taken when using the standard and to acknowledge what the standard is. The most common supplied is machined to 1.870" however for known applications such as Rig 801 a standard of 1.780" has been supplied. If you are trying to set the racks at a level that is different than the standard you do the math to determine what is the setpoint you are aiming for on the indicator dial. For example, if the proper rack setting is 1.830" and your standard is 1.870", (0.040" difference) the normal procedure would be to zero the indicator with the standard. Then adjust the rack linkage to the setting that is - 0.020" from the zero. Refer to the engravings

determine if you have a special standard.

**\*\*special note\*\*** Pay attention to the small indicator pointer as well so you don't inadvertently make settings that are off by 0.200".

### **Injector Timing**

Injector timing is independent of the rack setting. Different injector types are set at different flywheel degree points.

| Injector part # | Timing degrees |
|-----------------|----------------|
| 5229200         | 4 Deg BTDC     |
| 5229250         | 4 Deg. ATDC    |
| 5229335         | 0 Deg. BTDC    |

Certain applications may allow adjustments to this setting. depending on gas quality, engine load and turbo after cooling, advanced or retarded timing may be desired. Always start with the standard setting. If gas content is largely methane ">92%" and the after cooler system is optimized then advanced timing could provide greater thermal efficiency in both the diesel and the gas modes of operation. On the other hand if gas quality is low and air box temperatures are high a reduced timing may be necessary to avoid the lifting of the cylinder relief valves. The maximum advance setting for the timing on these injectors is 8 degrees BTDC. Consult ECI before attempting to adjust and operate an engine at this level. If an over advance setting is made to the cylinder the rocker movement will be greater than the movement of the injector and damage to the camshaft, rocker, injector and cylinder head will occur. Potentially requiring the replacement of all of these components



# Energy Conversions Inc.

Natural Gas power from EMD engines

Technical bulletin 20-002 3/5/96 Pg. 1 of 2

**Subject : Injector calibration for dual fuel converted engines**

**File name: tbinject.doc**

**Explanation:** Injectors used on engines converted to operate dual fuel differ only in there calibration. The diesel injectors contain all the same parts as the standard injectors. There have been three different part number injectors used in Dual Fuel operation to date. 5229335, 5229250 and 5229200. Normally these injectors are calibrated on a test stand with a rack length of exactly 7/8", stroked a number of times (300 or 400) and adjusted to match a calibration standard. For optimum dual fuel operation and balance, the injectors are calibrated at there pilot fuel setting.

The explanation given here assumes that the person doing injector calibration is already knowledgeable about operating the calibration machine.

The injector is now calibrated at a rack length of 1.880" it is then stroked a number of times dependent on injector part number. The injector rack slide is then adjusted so the injector delivers the proper level of fuel. The fuel feed pressure should be kept between 30 and 50 psi. The speed should be kept between 880 and 910 RPM. To hold the injector rack to the new (longer) position of 1.880" a simple extension should be added to the standard rack holding fixture. This extension can be obtained from ECI. After installation of the extension check the setting with a depth mic and make adjustments if necessary.

Insert the injector rack into the holding fixture. Because the rack is at its long position it is more difficult to seat it into the holder. By using a short push rod at the back of the injector rack it is easy to force the rack into the holding fixture. By performing adjustments you will find that some injectors are very sensitive and that a small fraction of a turn on the adjustment screw can make a fairly large difference.

Table 20-1

| Injector type | number of strokes | number of CC's |
|---------------|-------------------|----------------|
| 5229200       | 1600              | 45-55          |
| 5229250       | 1600              | 65-75          |
| 5229335       | 800               | 45-55          |
|               |                   |                |

The time for tests on injectors are longer due to the number of strokes. There are alternate methods of running the tests because of the low amount of fuel pumped. Especially useful on the 5229200 injectors you can set the test stand to run manual so as not to shut off at the time the counter is reached. Preliminary adjustments and inspections can be performed on fewer strokes. After you have fuel to a level that is visible in the column, note that level. Start the test and measure just the amount of change in level. You can run several of these tests back to back before draining the columns. When you think you have the level set then run a standard test.

It may be desirable to run a standard test on the injectors after they have been calibrated at the pilot fuel level just to note the level of shift in the delivery. If desired you can use the table supplied to record the variables associated with injector performance.

## Injector calibration record sheet Date \_\_\_\_\_

|    | Part<br>Number _____<br>Injector serial # | Std. delivery before<br>before pilot settings | Pilot level setting<br>after adjustments | Std. delivery after |
|----|-------------------------------------------|-----------------------------------------------|------------------------------------------|---------------------|
| 1  |                                           |                                               |                                          |                     |
| 2  |                                           |                                               |                                          |                     |
| 3  |                                           |                                               |                                          |                     |
| 4  |                                           |                                               |                                          |                     |
| 5  |                                           |                                               |                                          |                     |
| 6  |                                           |                                               |                                          |                     |
| 7  |                                           |                                               |                                          |                     |
| 8  |                                           |                                               |                                          |                     |
| 9  |                                           |                                               |                                          |                     |
| 10 |                                           |                                               |                                          |                     |
| 11 |                                           |                                               |                                          |                     |
| 12 |                                           |                                               |                                          |                     |
| 13 |                                           |                                               |                                          |                     |
| 14 |                                           |                                               |                                          |                     |
| 15 |                                           |                                               |                                          |                     |
| 16 |                                           |                                               |                                          |                     |
| 17 |                                           |                                               |                                          |                     |
| 18 |                                           |                                               |                                          |                     |
| 19 |                                           |                                               |                                          |                     |
| 20 |                                           |                                               |                                          |                     |
| 21 |                                           |                                               |                                          |                     |
| 22 |                                           |                                               |                                          |                     |
| 23 |                                           |                                               |                                          |                     |
| 24 |                                           |                                               |                                          |                     |

# RECOMMENDED SPARE PARTS LIST

## DUAL FUEL DIESEL ENGINE

| <u>Item</u> | <u>Description</u>                                                            | <u>Part Number</u> | <u>Manufacturer</u> | <u>Qty</u> |
|-------------|-------------------------------------------------------------------------------|--------------------|---------------------|------------|
| 001         | Piston                                                                        | 10-1002            | ECI                 | 4          |
| 002         | Piston Rings                                                                  | 10-1004            | Kaydon              | 4          |
| 003         | Cylinder Head                                                                 | 10-1005            | ECI                 | 4          |
| 004         | Cylinder Relief Valve                                                         | 10-1020            | ECI                 | 4          |
| 005         | Air Cylinder, Diesel Cont                                                     | 20-1110            | BW                  | 1          |
| 006         | Gas Inlet Valve Assy                                                          | 35-1402            | ECI                 | 4          |
| 007         | Filter, Gas Inlet Valve                                                       | P-18               | Aeroquip            | 16         |
| 008         | Gasket, GIV to Head                                                           | 35-1438            | PHO                 | 10         |
| 009         | Exhaust Temp. Sensor                                                          | xx50-1740          | Alnor               | 4          |
| 010         | Flywheel Pickup                                                               | 50-1728            | Dynalco             | 3          |
| 011         | Control Air Press. Sen.<br>Gas Hdr. Press. Sensor<br>Gas Pressure Transmitter | 50-1700            | Foxboro             | 1          |
| 012         | Water Temp. Sensor<br>Air Temp. Sensor<br>Gas Temp. Sensor                    | 50-1715            | ECI                 | 1          |
| 013         | Air Box Press. Sensor                                                         | 50-1705            | Foxboro             | 1          |
| 014         | Exhaust Temp. Sensor                                                          | xx50-1740          | Alnor               | 4          |
| 015         | D. P. Transmitter                                                             | 50-2021            | SMAR                | 1          |
| 016         | Power Supply, ECU                                                             | 60-1996            | ECI                 | 1          |
| 017         | Input Isolation Relay                                                         | MIAC5              | Gordos              | 10         |



| <u>Item</u> | <u>Description</u>                           | <u>Park Number</u>          | <u>Manufacturer</u> | <u>Qty</u> |
|-------------|----------------------------------------------|-----------------------------|---------------------|------------|
| 018         | Ouput Isolation Relay                        | MODC5MA                     | Gordos              | 10         |
| 019         | Cooling Air Filter, ECU                      | PA-2002                     | Solberg             | 5          |
| 020         | Switch, VTS                                  | 80-2311                     | Fenwal              | 3          |
| 021         | Gas Cut Off Valve<br>Main Gas Shut Off Valve | 90-2608                     | Sealco              | 1          |
| 022         | Rebuild Kit, GCOV,<br>MGSOV                  |                             |                     | 3          |
| 023         | Gasket, Gas Supply<br>Piping                 | 90-2669                     | FNW                 | 5          |
| 024         | O'Ring, Gas Hdr.                             | V137                        | Eriks               | 4          |
| 025         | Gasket, Load Block                           | 90-2418<br>(Modified Style) | ECI                 | 20         |
| 026         | O'Ring                                       | 230                         | Eriks               | 2          |
| 027         | O'Ring                                       | 238                         | Eriks               | 20         |
| 028         | Gas Hose Assembly                            | 90-2515                     | ECI                 | 4          |
| 029         | Fitting, GIV Air w/Filter                    | 35-1470                     | ECI                 | 5          |
| 030         | Magnet Valve                                 | 816-L 1                     | Graham White        | 1          |
| 031         | Gasket, Magnet Valve                         | 1702                        | Graham White        | 1          |
| 032         | Press Control Valve                          | VEP-321                     | Air                 | 1          |
| 033         | Diode                                        | 8421017                     | EMD                 | 4          |
| 034         | Shuttle Valve                                | SV-10-B                     | ARO                 | 2          |
| 035         | Starting Fuel Canister                       | 020-020                     | KBI                 | 2          |
| 036         | Hose, Air Control                            | FC-300-4                    | Aeroquip            | 50 ft      |
| 037         | Hose, GCOV to GFCV                           | 90-2644                     | ECI                 | 1          |

| <u>Item</u> | <u>Description</u> | <u>Park Number</u> | <u>Manufacturer</u> | <u>Qty</u> |
|-------------|--------------------|--------------------|---------------------|------------|
| 038         | Lead Wire, 3/16"   | 8245511            | EMD                 | 2          |

## Troubleshooting- Stationary Power

| Problem Area/Indication                     | Possible cause                                                                                                                                                                     | Recommended check or corrective action                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |
|---------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <p><b>Gas Fault</b></p> <p>Engine speed</p> | <p>Loose or damaged gas flow control valve linkage</p> <p>Sticking gas flow control valve</p> <p>Improperly set pilot fuel setting</p> <p>Sticking diesel fuel control linkage</p> | <p>Inspect the gas valve linkage to insure that it is not loose, damaged or improperly adjusted. Repair as necessary.</p> <p>Disconnect gas valve linkage from the governor. Work the lever of the gas valve; see that it is smooth and free and that spring returns. If the valve feels notched or sticky, service the valve per manufacturer's recommendations.</p> <p>Loose or improperly adjusted pilot fuel control rams can cause the minimum amount of fuel injected at low loads to be too high to maintain proper engine speed. Inspect and adjust the pilot rams if necessary.</p> <p>The diesel control ram may not be extending to the pilot fuel position, allowing too much fuel for no load. This problem can be aggravated by sticking injector linkages or control shafts. Inspect the movement of the diesel linkages by moving the layshaft by hand and checking for freedom of movement.</p> |
| <p>Valve sequencer</p>                      | <p>Loose sensor wires, damaged sensors</p>                                                                                                                                         | <p>The valve sequencer is part of the ECU. It could be complaining about one of several possible conditions during which gas operation is prevented. The signals received by the valve sequencer are evaluated for accuracy: they could be unclear, or the engine may not be ready for gas operation because of some other condition the valve sequencer detects. These could be low engine speed, high engine speed, missing crankshaft position signals, or too many crankshaft position signals per revolution. Note the fault as indicated on the VSuP board inside the ECU. Match the code to the table on page C-4 to determine the indicated problem.</p> <p>Inspect connectors to insure they are secure. Inspect sensors and wires for damage.</p>                                                                                                                                                      |

# Troubleshooting- Stationary Power

| Problem Area/Indication | Possible cause                                                                                                                                                                                                 | Recommended check or corrective action                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |
|-------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Valve Sequencer         | <p>Bad sensors</p> <p>Damaged or missing sensor targets</p>                                                                                                                                                    | <p>The signals the sensors produce can be measured with a oscilloscope inside the ECU. If the sensor is suspect due to poor signal quality, replace it.</p> <p>Inspect for missing or damaged targets. Repair or replace as necessary according to procedure on pg. H-6.</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |
| Exhaust Temperature     | <p>Bad sensor or damaged wires or connectors</p> <p>Improperly set pilot fuel or bad diesel injector</p> <p>Improperly set gas fuel load valve or failing gas inlet valve</p> <p>Damaged electronics board</p> | <p>Exhaust temperature faults can occur for several reasons. The reactions of ECU cylinder temperature readings can help diagnose the problem. For example, a cylinder temperature reading that bounces by large jumps, or erratically drops to near zero even during diesel operation, indicates a bad sensor or wiring. A temperature reading that looks good in diesel mode but drops off drastically after gas operation may indicate a inoperative diesel injector or gas valve. Temperatures that drift high or low when in the gas mode may indicate overfueling of gas or underfueling of the pilot fuel.</p> <p>The cylinder reading may be completely dead or may be making large jumps. Replace sensor or repair wiring as necessary.</p> <p>The cylinder reading seems to be OK for a short time after switching to gas, but then starts to drop out. If this is happening to one cylinder repeatedly, suspect a problem in the diesel injector. If more than one cylinder is affected, the pilot fuel amount should be increased as described on page 1D-2.</p> <p>Using the load valve, reduce the gas flow to the high temperature cylinder as described on page E-6. If problems persist, suspect problems with the GIV itself. Generally, after initial adjustment the load valves should not need further adjustment.</p> <p>Depending on the level of damage, the reading may be a large negative, with several other cylinders showing the same low reading. The erroneous readings will not change</p> |

## Troubleshooting- Stationary Power

| Problem Area/Indication | Possible cause                               | Recommended check or corrective action                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |
|-------------------------|----------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|                         | Failing power assembly                       | between fueling modes. Replace the AI/O board in the ECU, using static precautions described on page C-5.<br>Most obvious at light loads. The cylinder shows low temperature in both fuel modes and is unresponsive to adjustment changes.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |
| Water temperature       | Bad sensor<br>Bad wiring<br>Bad power supply | The water temperature will only be indicated as a fault if it is too high. Follow this table only if the actual water temperature is normal, but reads high at the ECU. If the engine water temperature is actually high, refer to standard maintenance procedures.<br>Check the calibration of the sensor as outlined on page H-4. Replace the sensor if it is bad.<br>Bad wiring may cause either a high or low reading depending on the nature of the damage. Wires shorted by bared insulation or moisture will generally cause a high temperature reading. Bad connections or broken wires will give a low temperature reading.<br>Measure the voltage between the two sockets of the sensor connector. If the voltage is above 5.2V, then the precision voltage source is failing. Replace the AT board in the ECU. If the voltage is below 4.8V then be sure there is no shorting in the wires causing the signal to be bypassed. If the wiring and connections are clean and dry but the problem remains, replace the AT board in the ECU. |
| Gas temperature         | Bad sensor                                   | The gas temperature is primarily used for calculating the gas flow into the engine. Follow this table if the gas temperature is normal, but reads high or low at the ECU. If the gas temperature is actually high or low (very unlikely), check the gas fuel supply system.<br>Check the calibration of the sensor as outlined on page H-3. Replace the sensor if it is bad.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |

# Troubleshooting- Stationary Power

| Problem Area/Indication | Possible cause                                              | Recommended check or corrective action                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |
|-------------------------|-------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Gas Temperature         | <p>Bad wiring</p> <p>Bad power supply</p>                   | <p>Bad wiring may cause either a high or low reading depending on the nature of the damage. Wires shorted by bared insulation or moisture will generally cause a high temperature reading. Bad connections or broken wires will give a low temperature reading.</p> <p>Measure the voltage between the two sockets of the sensor connector. If the voltage is above 5.2V, then the precision voltage source is failing. Replace the AT board in the ECU. If the voltage is below 4.8V then be sure there is no shorting in the wires causing the signal to be bypassed. If the wiring and connections are clean and dry but the problem remains, replace the AT board in the ECU.</p>                                                                                                                                                                                                                                                                                                                                                                                                                                            |
| Air box temperature     | <p>Bad sensor</p> <p>Bad wiring</p> <p>Bad power supply</p> | <p>The airbox temperature is monitored to determine the power capacity of the engine. The ECU will lower engine power output when air temperature is high. If the temperature is high, resulting in abnormal power loss, inspect the cooling system. If the ECU temperature reading seems in error then continue with this table.</p> <p>Check the calibration of the sensor as outlined on page H-2. Replace the sensor if it is bad.</p> <p>Bad wiring may cause either a high or low reading depending on the nature of the damage. Wires shorted by bared insulation or moisture will generally cause a high temperature reading. Bad connections or broken wires will give a low temperature reading.</p> <p>Measure the voltage between the two sockets of the sensor connector. If the voltage is above 5.2V, then the precision voltage source is failing. Replace the AT board in the ECU. If the voltage is below 4.8V then be sure there is no shorting in the wires causing the signal to be bypassed. If the wiring and connections are clean and dry but the problem remains, replace the AT board in the ECU.</p> |

# Troubleshooting- Stationary Power

| Problem Area/Indication | Possible cause                                                                                                                                                                                                            | Recommended check or corrective action                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |
|-------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Gas pressure            | <p>Closed control valves (manual or automatic)</p> <p>Leak detection system alarm</p> <p>Bad sensor or wiring</p> <p>Failing gas pressure regulator or low supply pressure to the regulator</p> <p>Plugged gas filter</p> | <p>The gas pressure reading is used to measure the gas flow into the engine. It is also used to detect gas pressure levels outside of operating limits. Improper gas pressure will cause a mismatch in the governor linkage controlling the two different fuels, which will lead to less stable operation when switching between fuel modes. Low pressure faults can indicate a gas flow restriction. A high pressure fault definitely indicates a problem in the gas pressure regulator.</p> <p>Check to see if the manual gas valve near the gas filter is closed or partly closed. Inspect the air line going to the automatic gas shut-off valve (GCOV) and determine that it is in fact open.</p> <p>If a gas leak or bad leak sensor is detected, the automatic gas valves will be closed. Inspect the system using proper precautions (see pages E-3, F-1 and F-2) if a leak has been indicated on the leak detection system.</p> <p>Using a hand-held gauge, check the pressure at the test point and compare it to the reading on the status panel. If the ECU reading is incorrect, inspect the supply power to the sensor by measuring the voltage at the 24V test point on the power supply board. If it is not approximately 24 volts, inspect the power supply and sensor wiring. If these are OK, replace the sensor.</p> <p>Improper gas regulator operation could result in either high or low pressure. High pressure is definitely due to improper regulator operation. If low pressure is indicated, measure the pressures upstream and downstream of the regulator to determine its condition. Service the regulator as required.</p> <p>The gas filter may be plugged if the gas pressure decreases with more flow, but bounces back as the flow decreases. Service the filter as described on page E-4.</p> |
| Airbox pressure         |                                                                                                                                                                                                                           | <p>An air box pressure fault may indicate a bad sensor or wiring. High air box pressure should only occur during gas operation, since air throttling is only done in the gas mode.</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |

# Troubleshooting- Stationary Power

| Problem Area/Indication | Possible cause                                                                                                                                                            | Recommended check or corrective action                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |
|-------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Control Pressure        | <p>Air throttle</p> <p>Bad sensor or wiring</p>                                                               | <p>Compare the ECU status panel reading with the reading of a hand-held gauge. If they are more than 2 psi apart, look for sensor and wiring problems</p> <p>If air box pressures over 22 psi are indicated, there may be problems related to the air throttle. Inspect the linkages and the air pressure control hardware. View the ECU display screen showing the air throttle PID numbers. The air box pressures should never be significantly higher than the set point. They may be lower than the indicated set point, however. A nonresponsive throttle valve could be caused by lack of control air pressure, poor electrical connections to the air pressure control valve inside the air service cabinet, damaged or plugged control air line to the valve, or a stuck or jammed valve.</p> <p>Using a hand-held gauge, check the pressure at the test point and compare it to the reading on the ECU. If the ECU reading is incorrect, inspect the supply power to the sensor by measuring the voltage at the 24V test point on the power supply board. If it is not approximately 24 volts, inspect the power supply and sensor wiring. If these are OK, replace the sensor.</p> |
| Control Air Pressure    | <p>Low air supply from air compressor</p> <p>Plugged air filter or other control air flow restrictions</p> | <p>Control air is used to activate gas inlet valves. Improper air pressure may cause the GIVs to respond poorly. Air pressure is supplied from the air start air compressor through a manual shut-off valve, filter, regulator and lubricator. Use a hand-held gauge and check the pressure at the test point and compare with the ECU display screen. If the readings differ significantly, look for bad sensor or wiring.</p> <p>Check the air pressure going to the gas system regulator from the existing compressor. Be sure that the manual valve is fully open.</p> <p>If the pressure is good when there is no air being used (i.e., during diesel only operation), but the pressure drops</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |



# Troubleshooting- Stationary Power

| Problem Area/Indication | Possible cause                                                                 | Recommended check or corrective action                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |
|-------------------------|--------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Airbox Pressure         | Improperly adjusted or faulty air regulator<br><br>Bad sensor or wiring        | <p>out when gas operation begins, inspect the air filter for fouling. Inspect the air system for restricted flow.</p> <p>If the air pressure is only slightly out of range, adjust the regulator. If the reading is high, the regulator is faulty and needs replacement. If the reading is low, inspect the regulator and air hoses for integrity.</p> <p>Using a hand-held gauge, check the pressure at the test point and compare it to the reading on the ECU. If the ECU reading is incorrect, inspect the supply power to the sensor by measuring the voltage at the 24V test point on the power supply board. If it is not approximately 24 volts, inspect the power supply and sensor wiring. If these are OK, replace the sensor.</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |
| Gas Header Pressure     | <p>Stuck gas cutoff valve or air supply</p> <p>GIVs not operating properly</p> | <p>Gas header should have little or no pressure when in the diesel mode. The control system assumes there is a problem if excessive header pressure exists. View the status panel screen that shows the value <b>HdPr</b>. If the pressure is &gt;70 psi and is constant, then check the gas cutoff valve. Check for bad sensor or wiring. If the pressure is low and goes high only when gas operation is attempted, check the GIVs.</p> <p>Check to be sure that there is no actuating air applied to the gas cutoff valve. If no air is applied, the vent valve should be venting. There should be no power applied to the GR/R1 solenoid valve. If the valve has power, inspect electronic controls for possible cause. If these are OK, then shut off the gas supply manually, vent the trapped gas (see gas precautions, page A-1), and inspect the gas cutoff valve.</p> <p>If the GIVs fail to operate due to electrical or air supply problems, gas header pressure will go high when attempting to switch to the gas mode. Check the air supply to the GIVs. Check the valve sequencer inside the ECU and see that it is sequencing the valves; if it is not, replacement may be necessary. Check the control wiring.</p> |

# Troubleshooting- Stationary Power

| Problem Area/Indication                                                    | Possible cause                                                                                                              | Recommended check or corrective action                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |
|----------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Gas Header Pressure                                                        | Bad sensor or wiring                                                                                                        | Using a hand-held gauge, check the pressure at the test point and compare it to the reading on the ECU. If the ECU reading is incorrect, inspect the supply power to the sensor by measuring the voltage at the 24V test point on the power supply board. If it is not approximately 24 volts, inspect the power supply and sensor wiring. If these are OK, replace the sensor.                                                                                                                                                                                                                                   |
| Power Output (kW)<br>(For units with VG8 governors and automatic controls) | Malfunctioning Synchronizing motor on governor or associated wiring<br><br>Bad kW transducer or associated wire connections | Negative values indicate a damaged sensor or electrical connection. High values may indicate a control malfunction.<br><br>View the status panel digital output screen. The GDN dot should be blinking on and off. If so, then the ECU is trying to lower the load but the motor on the governor is not responding. If the ECU is not trying to lower the load, inspect variables affecting load control: kW reading, air box temperature reading.<br><br>Check the accuracy of the ECU kW reading compared to switch gear house meters. If they are different find the cause and repair or replace as necessary. |
| Power Supply Status                                                        | Blown fuse                                                                                                                  | Monitored by ECU to prevent improper operation in gas mode due to irregular supply voltage. The information on the ECU screen is affected by four of the five power sources generated on the power supply board inside the ECU. Information may be logged at the fault history after power is restored.<br><br>A blown fuse probably indicates a bad power module on the power supply board. Replace the power supply board if a new fuse blows again immediately. Shorted outputs of the power modules may blow the input fuse. Inspect for damaged wires and possible short circuits.                           |

# Troubleshooting- Stationary Power

| Problem Area/Indication | Possible cause          | Recommended check or corrective action                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |
|-------------------------|-------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Power Supply Status     | Overheated              | The power modules have built-in temperature limits. High temperature causes them to turn off. When cooled off they will once again provide power. If high temperature is suspected, inspect the ECU cooling fan.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |
|                         | Overvoltage output trip | If the voltage of the module is >15% of its rated output voltage, the module will turn itself off. In this event, the incoming power must be switched off before the module will supply power again. Overvoltage can occur with a rapid load change from full on to full off. However, it should not occur in normal operation. Repeated occurrences are cause to replace the power supply board.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |
|                         | Short circuit           | Shorting the output of the power supply modules will cause the module to limit current by reducing the output voltage. Repair the short circuit and the supply should regain its output voltage.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |
| VTS fault               | Gas Inlet Valve failure | <p>The Valve temperature switches located on gas inlet valve (GIV) are wired in series and will indicate to the controller that there is a hot valve and gas operation must be stopped. Engine shut down will occur within 1- 1/2 minutes if the hot signal does not reset.</p> <p>If there is a bad or improper operating gas valve it should be detectable by a load block that is noticeably hotter than the others. If the engine has shut down, be careful because the load block could be very hot. Change the GIV and the gas jumper hose that has been overheated even though it may look fine.</p> <p>There are three possible reasons for a gas valve to overheat. (1). A damaged sticking or malfunctioning solenoid valve on top of the GIV may cause the valve to stay open too long and allow compressed air to overheat the valve. (2). A damaged or distorted valve head or valve guide causing the valve seat to leak. (3). A failure on the electronic control side whereby the valve is held open and not closed during the remaining cycle.</p> |

# Troubleshooting- Stationary Power

| Problem Area/Indication   | Possible cause                                                | Recommended check or corrective action                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |
|---------------------------|---------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|                           | Bad valve temperature switch or broken wire.                  | <p>If either #1 or #2 is the cause, then changing the valve is all that is necessary. However, if #3 is the cause, then gas operation is first attempted that the red indicating lights are inspected to determine that the cylinder that failed is being cycled and not staying on. If it appears to stay on, immediately stop gas operation and change out the board.</p> <p>If there is no heat level indication on the load blocks, and particularly if the VTS signal does not reset, there is most likely a bad connection or a bad switch. Check the circuit for where the voltage is no longer present (most commonly these are a 24V circuit). The wiring is laid out so that the chain of switches and the power starts at the right bank rear cylinder, daisy chains to the front, crosses over to the front of the left bank, daisy chains to the rear and returns to the connector. Repair or replace components as necessary.</p> |
| <i>ECU gas condition</i>  |                                                               |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |
| Water temperature         | Engine just started (too cold)                                | Gas operation requires the engine to have reached a stable operating temperature. If engine temperature has not yet reached its minimum level, the status panel will display the engine water temperature. If it is known that the engine is warm enough to run on gas (>150°F), inspect the sensor as described on page H-4.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |
| Engine speed              | <p>Engine speed too low</p> <p>Bad speed sensor or wiring</p> | <p>The engine speed must be &gt;800 RPM for gas operation to start</p> <p>If the speed is known to be &gt;800 and the speed indicated by the ECU display is incorrect, then inspect the connections on the sensor, insure that the electrical connector is tight, inspect the wiring and replace the sensor if necessary. If this fails to solve the problem, then internal ECU diagnostics are required.</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |
| <i>ECU display report</i> |                                                               |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |
| Differential pressure     | Differential pressure sensor is out of calibration            | Follow the procedures for calibration of the DP sensor on page H-3.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |